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Technology Review

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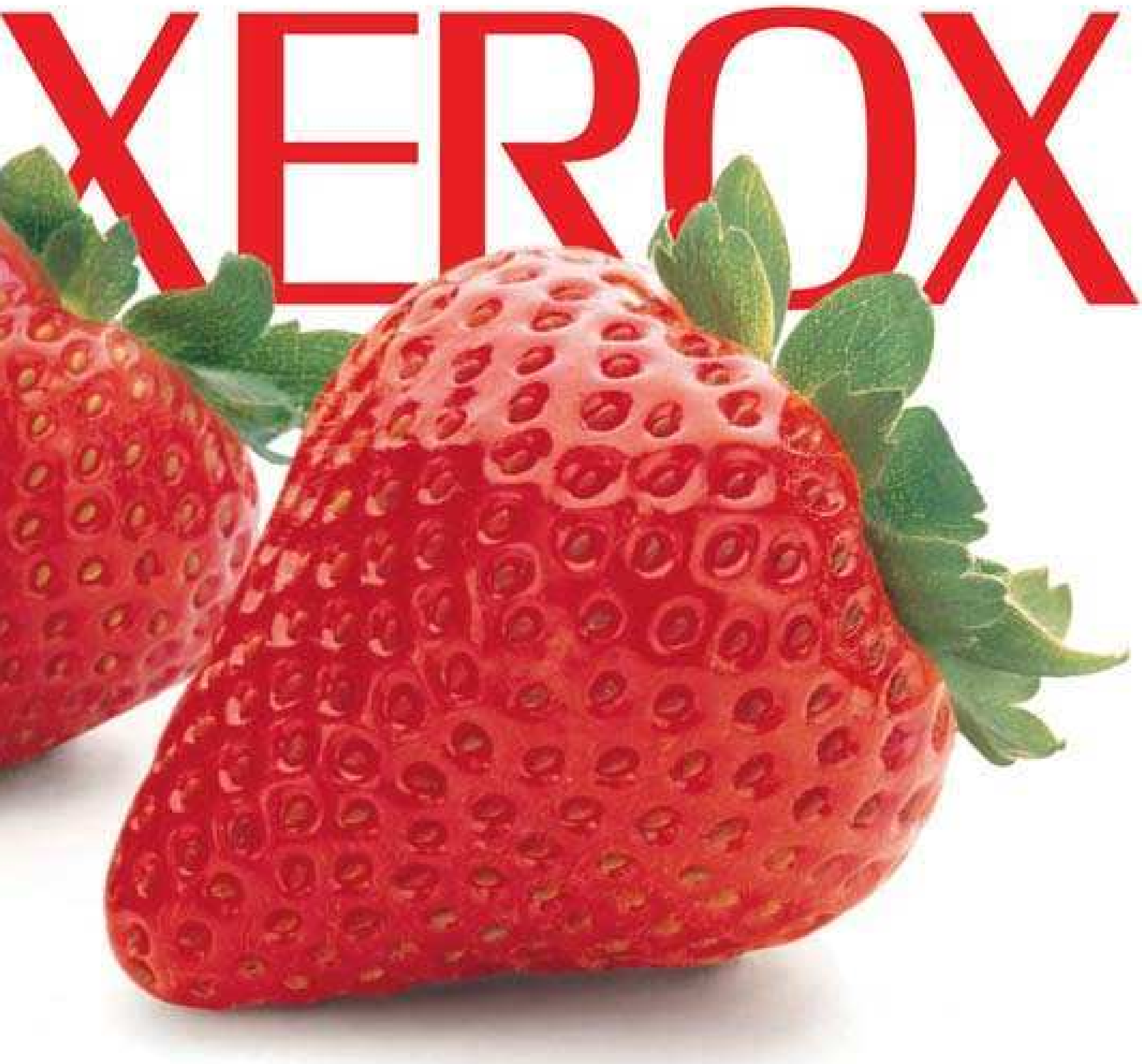
XEROX

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Volume 108, Number 2

Methuselah's prophet

Aubrey de Grey is a computer scientist at the University of Cambridge who thinks he can reverse aging in humans by treating it as an engineering problem. He's achieved some fame for the outlandishness of his views. Sherwin Nuland, professor of surgery at Yale's School of Medicine, profiled de Grey and found him brilliant—but also nuts.

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Cover photograph by James Day

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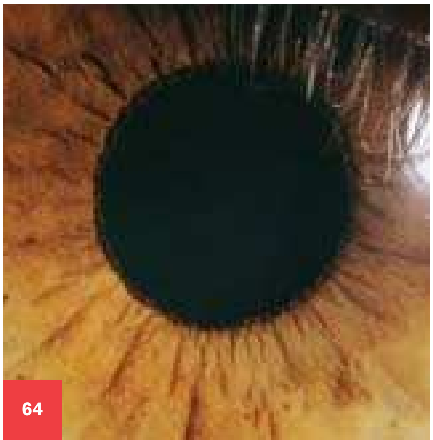

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PEOPLE

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From the Editor Jason Pontin

Against Transcendence

Science fiction is to technology as romance novels are to marriage: a form of propaganda. Both recapitulate in narrative form the fondest illusions of the practitioners of a commonplace but difficult activity, and so contrive to make the ordinary seem exhilarating.

Technologists spend their days devising novel solutions to discrete problems. The problems, if not the projects with which they are associated, are often boring. But in science fiction, technologists are heroic. The future is interesting because of the influence of technology. But most notably, in science fiction, technology always possesses a pseudoreligious quality. Technology, it is implied, will somehow allow us to transcend our ordinary, human selves.

When the science fiction writer and journalist Bruce Sterling was asked why so many science fiction novels ended with their heroes transcending their circumstances, abilities, or bodies, he was dismissive. "It's just a riff," Sterling answered. "The element of transcendence is just a feature of the SF genre, like feedback in rock music. People who take that stuff seriously end up turning into trolls....H. P. Lovecraft was a big fan of that cosmic-type stuff. That may be okay for him, but from the outside what you see is this pasty-faced guy eating canned hash in the dim corner of a restaurant, hands trembly, and a gray film over his eyes."

> When technology appropriates the transcendental it becomes science fiction. Technology is most useful when it is most human.

Most technologists believe in transcendence some of the time, and some technologists believe in it all the time. At those moments when they believe in it, they're crazy. When they believe in it completely, they've become trolls.

Throughout the last two issues of *Technology Review*, our subjects have appealed to transcendence in order to explain their projects. Last month, Jason Epstein, the retired editorial director of Random House, wrote of the occasion when he first saw a machine print a book on demand from a digital file, "It was a transcendent moment" *("The Future of Books," January 2005, p. 60)*. This month, W. Kent Fuchs, the dean of Cornell University's college of engineering and a minister, remarks in a profile, "Technology is like religion," because the two have similar goals and can be similarly misused *("Cornell's Minister of Technology," p. 21)*.

In the case of Aubrey de Grey, the subject of our story on anti-aging science *("Do You Want to Live Forever?" p. 36)* by Sherwin Nuland, the hunger for transcendence could not be more explicit or more complete: de Grey, a computer scientist at the University of Cambridge's department of genetics, believes he can defeat death by treating human aging as an engineering problem. When I wrote to ask why he hated aging so much, he wrote back, "Aging is repulsively gradual." Death from aging, he said, was "barbaric." De Grey thinks he is a technological messiah.

But what struck me is that he is a troll. For all de Grey's vaulting ambitions, what Sherwin Nuland saw from the outside was pathetically circumscribed. In his waking life, de Grey is the computer support to a research team; he dresses like a shabby graduate student and affects Rip Van Winkle's beard; he has no children; he has few interests outside the science of biogerontology; he drinks too much beer. Although he is only 41, the signs of decay are strongly marked on his face. His ideas are trollish, too. For even if it were possible to "perturb" human biology in the way de Grey wishes, we shouldn't do it. Immortality might be okay for de Grey, but an entire world of the same superagenarians thinking the same kinds of thoughts forever would be terrible.

Most responsible biogerontologists are more cautious about the applications of anti-aging science. They hope that when we understand why and how human tissues age, we will be able to better treat some of the chronic diseases of old age, like dementia, senile diabetes, or heart disease. (To learn how mitochondria, whose function declines with age, might be implicated in some of these diseases, see "Trouble in the Cell's Power Plant" in "Synopses," p. 83.) This would, in the jargon of geriatricians, "compress the morbidity" of the elderly: the debilities of old age might be restricted to a relatively short period of time before we die. Because some of these chronic diseases are eventually fatal, or have fatal complications, some of us would live longer, too—at least a little bit. But very few who have studied biogerontology think we'll ever transcend our mortality. As Nuland remarked to me, "Aging is not a disease. Aging is the condition on which we are given life."

When technology appropriates the transcendental, it becomes science fiction. Transcendence is not a part of this world, or any world that we know directly. We are alone with ourselves, and even if the application of biotechnology to human nature made us something else, we would remain creatures limited in space, time, and knowledge. Technology is most useful when it is most human in scope. Then, technology offers something close to happiness (even if ultimate happiness eludes us) by providing us with more expansive lives.

Write to me at jason.pontin@technologyreview.com. ■

Letters

NUCLEAR-WASTE DISPOSAL

In his important article ("A New Vision for Nuclear Waste," December 2004), Matthew Wald proposes waiting until we can develop a waste package that would keep radionuclides out of the environment for a few thousand years. Well, we don't have to wait; we already have that technology. If we were to encase the spent fuel in copper and place it in a repository below the water table (a reducing environment), we could be assured that neither the waste package nor the spent fuel itself would react with water and release radionuclides. Sweden is planning to do just this. The problem with Yucca Mountain is that it's dry—an oxidizing environment. Furthermore, Wald advocates a single centralized facility to store waste in the interim. But he does not consider the cost of transporting the spent fuel to this facility or the security risks that transportation entails. It is arguably safer, and cheaper, to keep the spent fuel at reactor sites in dry casks than on the nation's highways, subject to sabotage.

Allison Macfarlane
MIT Security Studies Program
Cambridge, MA

The Yucca Mountain project is doomed to failure if one examines the Department of Energy's pathetic record of performance on dozens of poorly managed megaprojects, including the superconducting supercollider, the laser fusion program, the National Ignition Facility, and the Clinch River breeder reactor. All were sold to Congress by one of DOE's overzealous fiefdoms, and approved based on pie-in-the-sky promises. Then, when actual construction was initiated, the same old story came to light in the form of delays and cost overruns. True to form, the Yucca Mountain project is proceeding without a clear set of criteria while spending billions of ratepayers' dollars and is now more than 10 years behind schedule.

Thomas Bullock
West Covina, CA

Matthew Wald makes the simplistic statement that Yucca Mountain "won't work," but then concludes that the waste should be stored in casks at one central location. Yet that is precisely what is planned at Yucca Mountain. Totally overlooked is the fact that the waste will be easily retrievable from the repository, just as it would be at an above-ground storage site, until we choose to seal it. We do not give up any options by proceeding with Yucca Mountain. If we find a better way to process and dispose of the waste during that time, it can be transferred to another facility. In the more likely event that we decide that it is fine just where it is, based on more detailed analyses showing satisfactory repository performance or, better yet, by coming to our senses concerning acceptable doses and risks, we will not have to do anything further. Regardless, Yucca Mountain will provide safe, secure storage for any interim period.

James E. Hopf
San Jose, CA

The idea in this article seems like a plot from *The Simpsons*: "This week, Homer contracts with Smithers to dispose of Mr. Burns's nuclear detritus by building a pad in his backyard. Bart has other plans." Shortsighted planning got us this far in our pursuit of nuclear energy; why not continue with the policy? Our children's children's children will be able to handle this deadly poison, since they will be motivated by survival. This has been the recipe for modern man and his technology.

Dan Thomas
Cambridge, MA

In his superb article, Wald failed to point out that the plutonium in the spent fuel rods from nuclear power plants is not suitable for making atomic bombs: approximately 30 percent of the plutonium-239 is converted into plutonium-240, which is a prolific emitter of neutrons, and would cause any atomic bomb made with it to fizzle instead of explode. Separating the two plutonium isotopes is not feasible because of the small difference in their atomic weights. It was a lack of knowledge about plutonium-240 and fear that the plutonium in spent fuel rods could be used for weapons that led President Carter to stop all reprocessing of spent fuel in this country, and to order a search for a place like Yucca Mountain where it would be buried permanently. This has resulted in an enormous waste of money and has put the United States at a disadvantage to countries that practice nuclear recycling and that are continuing to build nuclear power plants.

Alfred C. Schmidt
Hillsborough, CA

STEM CELL POLITICS

In writing that technology is morally neutral ("Christopher Reeve and the Politics of Stem Cells," December 2004), editor in chief Jason Pontin is apparently arguing that any moral problem comes from how technology is applied, not the technology itself. But a technology is simply a set of methods for accomplishing a goal. Both the methods and the goal can have a moral component. Technology developers are no more exempt from responsibility for the moral components of their work than are the people who will eventually use the technology.

Adrian Nye
Austin, TX

Contrary to the statement in Pontin's editorial, Democratic vice presidential candidate John Edwards did not suggest that embryonic stem cell research "might have permitted the quadriplegic Reeve to walk." Senator Edwards actually said, "If we can do the work that we can do in this country—the work we will do when John Kerry is president—people like Christopher Reeve are going to walk." Edwards was clearly referring to *future* research and expectations for people like Reeve.

Steven Sussman
Littleton, MA

Jason Pontin responds: Even a technology that is invented for an immoral purpose may later find benign application. Regarding the statement by John Edwards: while careful to say that stem cell research would help people "like" Christopher Reeve, the senator was transparently exploiting sympathy for the actor for political purposes.

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Each readme is an executive summary
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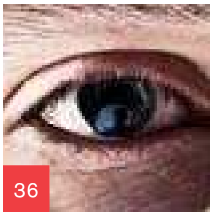
stripped to its logical bones.
Each concludes with a call to action.

BIOGERONTOLOGY

Be Sane about Antiaging Science



Spinoza said that all things wish to continue in their own form forever: the human desire to live longer is instinctive. And we're getting better at it. The life expectancy of a person born in the United States in 1900 was 47 years; for a baby in 2002, it was 77 years and a few months. This remarkable improvement is due to a century of medical advances, particularly those involving the treatment of severe infections, traumatic injuries, and certain contagious diseases. But average life expectancy has risen extremely gradually in the last 50 years. Using conventional medicine, human beings in wealthy nations seem to be living about as long as they can.

This is because we haven't cured aging or the diseases of aging. Even if you stay healthy most of your life—avoiding car accidents, various fatal infections, and any number of deadly ailments—your body will age and die. But is the aging process biologically immutable? That's the question raised in this month's profile of Aubrey de Grey, a University of Cambridge computer scientist and self-taught biologist who loudly and angrily argues that there is nothing inevitable about aging and death *(see "Do you Want to Live Forever?" p. 36)*. Aging, he says, is "repulsive" and death from aging "barbaric." De Grey, who lectures and publishes widely on the topic, claims that by "perturbing" our cellular processes, we could live for thousands and thousands of years. Further, he says that we will be able to do this 25 to 100 years from now.

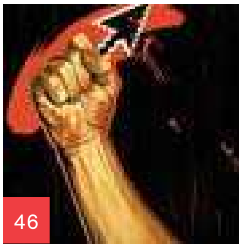
Is this absurd? Yes, of course it is. Yet recent breakthroughs in molecular biology and genetics have created an exciting new field called biogerontology that promises to explain why organisms age. And for the first time, serious scientists can imagine ways to actively alter this process. Physician Sherwin Nuland traveled to Cambridge, England, to see just how de Grey's radical vision fits into this emerging field.

Sherwin Nuland would not be satisfied by anything less than rigorous scientific reasoning and evidence. Indeed, it's hard to imagine a writer more qualified to profile the eccentric de Grey. A clinical professor of surgery at Yale University's School of Medicine, Nuland is also an expert on medical history and bioethics. He has written several books on the subject of human biology, including *How We Die*, which won the National Book Award in 1994. He has been published in the *New Yorker*, the New York *Times*, and *Time*.

What does Nuland think of the bearded de Grey's offer of immortality? He isn't buying it. Yet he presents de Grey as a compelling and brilliant visionary who forces listeners to reconsider what they know about aging—and what it would mean to radically extend the life span of humans. Nuland concludes that de Grey's strategies to eliminate aging won't work. And for social, medical, and cultural reasons, he says, that's a good thing.

Nuland's story on de Grey suggests it's time to think about the medical and ethical implications of antiaging research. Those in the research and medical communities must explain to the public the priorities and goals of such research. Informed consumers of science and technology should be able to separate the hyperbole of de Grey's claims from what the science could offer.

That's real enough. While it is highly unlikely that aging can be permanently halted at the cellular level, antiaging science might allow doctors to "compress the morbidity" of their patients: that is, reduce the amount of time geriatric patients suffer from the chronic diseases of old age like heart disease, macular degeneration, senile diabetes, or dementia. Such therapies would also extend human life—at least a little bit, anyway. Human beings could live beyond the age of 80 or 90, and in relatively good health. And while that's not immortality, it offers something like happiness on a reasonable, human scale. ■



SECURITY

Deprive Terrorists of the Internet

Web hosting companies must start to behave more responsibly.

Is an Internet clampdown coming? Very possibly—unless Internet Service Providers (ISPs) and Web hosting companies begin to behave more responsibly.

Pointing to the growing trends of online fraud, copyright infringement, hacker attacks, and spam, Jonathan Zittrain, codirector of the Berkman Center for Internet and Society at Harvard Law School, says law enforcement, government, and the online industry itself will eventually foist upon us a more "battened-down" Internet—one that's more secure, perhaps, but also far less flexible and amenable to creativity and commercial opportunity. In other words, the technology promise of the Internet is under serious threat. This month, *Technology Review* adds another item to Zittrain's list of the Internet's dysfunctions: its increasingly effective exploitation by terrorist organizations.

The several facets of this deeply troubling trend are described in "Terror's Server" on page 46. Law enforcement officials are increasingly worried that online fraud is funding terrorist atrocities: Imam Samudra, convicted mastermind of the Bali disco bombing of October 2002, has penned a jailhouse memoir that offers a primer on online fraud for his fellow terrorists. More broadly, jihadists are making good use of the Net, with websites that recruit members, solicit funds, and promote violence. Finally, the Internet is enabling a ghastly new spectacle: tens of millions—perhaps hundreds of millions—of people around the world have gone online to watch struggling hostages in Iraq have their heads sawed off.

> Jihadists are making very good use of the Net, with websites that recruit members, solicit funds, and promote violence.

There are some possible technological fixes for security agencies and others who want to deprive terrorists of the use of the Internet. These include chat-room screening algorithms and new anti-fraud measures that authenticate e-mail. But Web hosting companies might also consider exercising more editorial judgment about online content. While any efforts at blocking and filtering pose technological challenges and would raise libertarian ire, surely these companies could be more vigilant and at least try to limit the posting and propagation of the most offensive and violent material.

This would not restrict free speech in any novel way. In most cases, it would require only the enforcement of existing terms of service. These terms generally say users must not post any kind of hate speech, racist comments, violent images, or illegal content like child pornography or copyrighted material. Currently, Web hosting companies enforce these terms only when people complain. We recognize that screening content up front, as broadcasters and editors do in traditional media, would be extremely difficult, if not impossible. But ISPs and Web hosting companies increasingly seem to want to be new-media broadcasters without assuming the responsibility that that entails—and its costs.

If the online industry doesn't take a more active stance, events may overtake it. Laws tend to change when some awful event creates public demand for legislation. In the United States, September 11 created the Patriot Act, with its erosion of civil liberties and privacy. ISPs should begin to behave more like traditional broadcasters, screening obscenely violent content—and they should do it soon. If they don't, it's not inconceivable that, some day, legislative bodies—spurred by some online outrage yet to come—will do it for them.

Videos of politically motivated beheadings are now freely available online. They are posted to inflame the zealous and titillate the jaded. Only the most ardent of libertarians would hesitate to join us in saying, Enough. ■

BIOTECHNOLOGY

Openly Regulate GMOs

New Zealand is providing an example of effective regulation.

New Zealand has recently become one of the world's most inviting places to create, exploit, and market genetically modified organisms (GMOs). It did so by enacting responsible and effective regulations. Hooray for the New Zealand government.

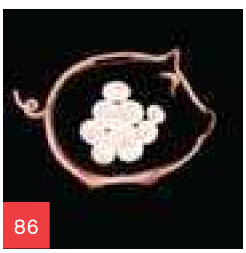
The benefits of GMOs are only beginning to be felt, in the form of higher crop yields and a handful of experimental protein-based pharmaceuticals; their long-term impact could be much more significant. But public opposition to the notions of tinkering with the genomes of living things, releasing transgenic creatures into the environment, and using GMO products in food is very real. In Europe, the outcry over genetically modified crops from Monsanto, Aventis, and other companies culminated in outright bans on some genetically modified foods. In the United States, public fears over what some have called "Frankenfoods" have led some companies to pull products from

the market and rein in R&D. Indeed, why invent products like new variations of pest-resistant potatoes or corn when huge multinational companies such as McDonald’s and Frito-Lay won’t dare to buy them?

But as we learn from the case study on page 28, “New Zealand: Green Haven for Biotech?”, the level-headed folk of New Zealand may have found a way around such impasses. There is nothing magical about their solution. It relies on regulations laboriously devised to address the concerns of environmentalists, scientists, and businesspeople alike. The regulations’ goal, in the words of Marion Hobbs, New Zealand’s environmental minister, is to “provide a practical framework for proceeding with caution in the management of new organisms (including GMOs) while preserving opportunities.” In a country often noted for its strong environmental sensibilities, it seems compromise has won out.

First and foremost, the regulations, enacted in 2003, ensure public involvement in the approval and monitoring of field releases of GMOs. They also demand spot checks of active projects and regular publication of status reports on the Web. At the same time, the regulations require that biotech companies respect the customs of indigenous Maori tribes, who have both particularly strong beliefs about the sanctity of the natural world and growing political power in the country. One result of the new laws is that the regulations help to keep GMO research on track even in the face of preëmptive legal attacks over potential harms, attacks that have slowed field tests and drained biotech companies’ coffers in other countries. These provisions are attracting the attention of biotech manufacturers and investors, who are pleased to have discovered an environment with clear—and politically legitimate—research guidelines.

Every country must weigh the medical, agricultural, and economic opportunities presented by genetically modified organisms against the potential risks. Governments should go out of their way to regulate GMOs in a way that is fully transparent and open to public comment. But that’s only half of the formula: companies and investors will be more willing to take financial risks on biotechnology products if a government “seal of approval” carries real weight. If businesses and regulators want to stimulate GMO research in their own countries, they should keep an eye on the antipodes. ■



INVISIBLE COMPUTING

Time to See the Opportunities

Vendors must market a viable vision for this technology.

Things looked bleak when the dot-com economy of the late 1990s collapsed, and information technology spending plummeted; but most longtime technology executives weren’t terribly worried. They were confident that the “next big thing” would spur excitement and industry growth soon enough. After all, in the 40 years since the information technology industry began, this boom-bust-boom-again cycle had repeated itself quite predictably. Before the Internet, there was client/server computing; before that, PCs; and before that, minicomputers and mainframes. When the bubble popped, many information technology experts remained confident that a new wave of technology would sweep the market and bring success to those vendors who persevered.

Technology leaders need to market invisible computing in a way that cracks open the wallets of CIOs and consumers alike.

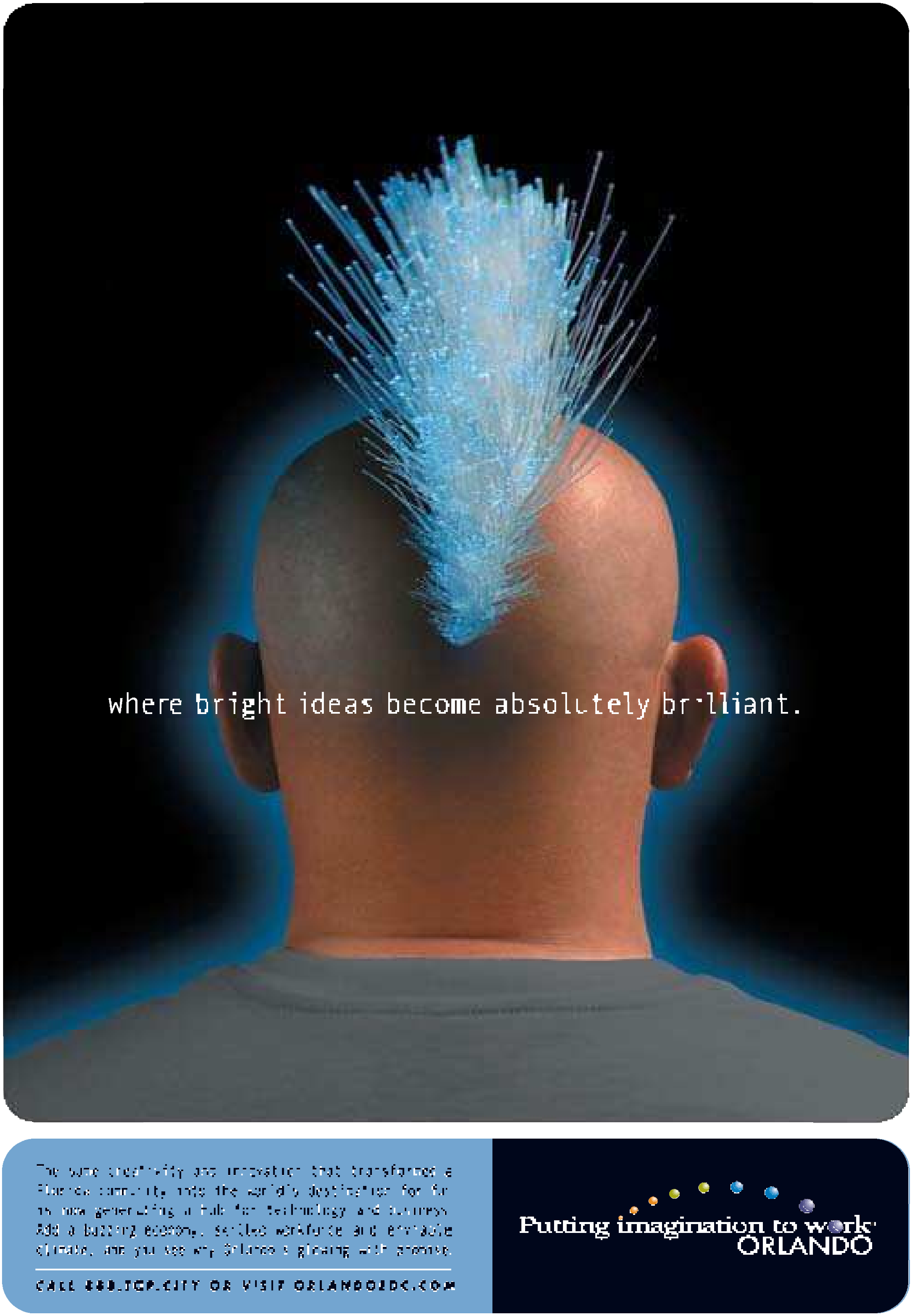
But four years later, domestic growth in technology spending is still stagnant. No next big thing has emerged—at least not one that you can sell. Finally, however, technologists are in agreement about what that next big thing will be.

Call it “pervasive,” “ubiquitous,” or “invisible” computing, it will make intelligence as common as electricity. While it remains difficult to quantify the market for invisible computing, analysts now predict that it will reach $675 billion by 2008, and that by 2012 there will be an estimated 16.4 billion networked devices around the world *(see “Data Mine,” p. 86)*.

A world of pervasive or invisible computing will contain a dizzying number of intelligent devices—computers and cell phones, of course, but also cars, toys, refrigerators, soup cans with sensors, and so on—that interconnect via an intricate series of networks. Researchers at MIT’s Computer Science and Artificial Intelligence Laboratory refer to their version of the technology, which they have been working on for several years, as Project Oxygen, because that’s how free, available, and simple access to computing will be. This vast new network of interconnected devices should, its promoters predict, create greater productivity gains than any previous information technology.

Although it’s tough to market oxygen, it is possible to sell invisible computing’s underlying technologies: wireless, instant messaging, Web services, customer relationship management, and asset management. That’s what technology vendors want enterprise buyers to get excited about. But here’s the cynical truth: in order for a technology boom to get going, market researchers at companies like International Data Corporation or Forrester need to promote it. And for consumers to buy into a concept, they must be able to readily grasp it. In other words, technology leaders need to learn how to market invisible computing in a way that cracks open the wallets of CIOs and consumers alike.

They might learn a lesson from Intel and its creation of the Centrino brand *(see “Intel’s Centrino Solution,” p. 31)*. The chip maker synthesized a market basket of compelling technologies into a single brand that communicated “computing on the go.” Vendors with a substantial stake in the future of invisible computing could likewise create a coherent, easily understandable combination of components to sell as a package. Project Oxygen has succeeded in doing this for the research community. It’s time for the vendor community to make enterprises and consumers aware of the invisible-computing wave and get them excited enough to want to buy into it. ■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If only it were this easy

A crisis in Nigeria highlights the tangled politics of vaccination

IN A FRACTIOUS world, there is one enemy that has had a unique ability to compel people from all countries to lock arms: poliovirus. For more than 15 years, the World Health Organization (WHO) has coördinated mass-immunization campaigns in an effort to eradicate poliovirus, a goal it hopes attain by the end of this year. If this Global Polio Eradication Initiative succeeds, it will join the smallpox eradication program as one of the greatest medical triumphs in history. So there was a great gasp in 2003 when northern Nigeria broke ranks with the rest of the world and banned the polio vaccine, triggering an outbreak that soon spread to 12 neighboring countries—and illustrating once again how easily the virus can take advantage of any chink in our collective armor. Then again, the Nigerian setback may unintentionally have given the initiative the added fuel that it needs to cross the finish line on time.

Since its inception, the polio eradication program has reduced the incidence of paralytic polio by 99 percent, from some 350,000 cases a year to fewer than 1,000. As of 2003, the virus was circulating only in Nigeria and five other countries. But in the middle of that year, Muslim clerics in northern Nigeria denounced the vaccine, claiming it contained hormones intended to sterilize girls or that it was contaminated with HIV. By the fall, northern Nigerian politicians and health ministers had banned the immunization campaigns in Kano and two other states—a move seen as a nod to the prestige of the Muslim clerics and a slap at both the West and the country's Christian president, Olusegun Obasanjo. By year-end, Nigeria had reported more than 355 polio cases,

surpassing India and Pakistan for the first time. “Nigeria is a painful example of the potential impact of vaccine refusal,” says Daniel Salmon of Johns Hopkins University’s Bloomberg School of Public Health.

As cases continued to mount in Nigeria, scientists confirmed that the virus had hopped a few borders and paralyzed a child in Ghana, which had not had a case of polio in three years. Soon, they found evidence of Nigerian-like polio strains in 11 other sub-Saharan African countries that had been polio-free for at least three years and so had scaled back their own mass-immunization campaigns. “When Nigeria began to export virus, the virus found an easy home,” says WHO epidemiologist David Heymann, who heads the Global Polio Eradication Initiative. “The tragedy of Kano is that Africa now has 89 percent of all paralyzed children.”

> “What Kano has done is sensitized a whole new series of partners in eradication.”

Although the eradication program has elaborate plans for combatting outbreaks of the virus, combatting an outbreak of anti-vaccination fever presented a much different challenge. “We worked really hard behind the scenes,” says Heymann, who personally called the governor of Kano state every day for three weeks. The eradication program also encouraged the Organization of the Islamic Conference—which represents 57 states with large Muslim populations, including Nigeria—to issue a resolution in October 2003 that urged members to step up their eradication efforts. And in February 2004, the program arranged for a Nigerian commission to visit polio vaccine manufacturers in (predominantly Muslim) Indonesia, as well as South Africa and India.

In July 2004, after three Nigerian government commissions agreed that the polio vaccine was safe, Kano state lifted its ban and agreed to accept vaccine from Indonesia. But the ban had already strained the coffers of the eradication program. Its budget through 2005 is $3 billion, with more than $500 million coming from Rotary International. Heymann estimates that it is still $200 million shy of what’s needed, and he says the Nigerian ban accounts for more than half of that shortfall.

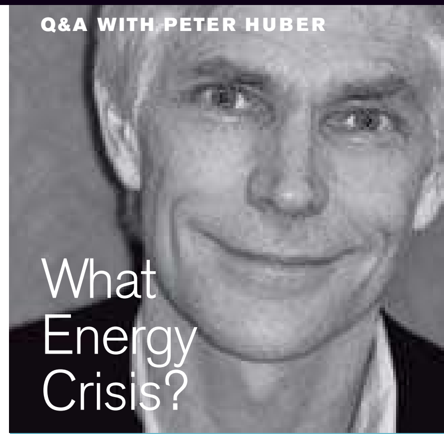
There is a silver lining. “What Kano has done is sensitized a whole new series of partners in eradication,” says Heymann. “In the long term, it’s brought solidarity among Islamic countries.” This is especially important given that four of the countries outside of Nigeria with the biggest polio problems are Pakistan, India, Afghanistan, and Egypt. And because of the setback, 25 African nations agreed to launch the largest immunization campaign ever staged, setting out four months ago to immunize 80 million children. In October 2004, at the start of that campaign, Heymann projected that polio cases would start to decrease by January. If WHO finds the funding, he says, it will say good-bye to polio by the end of this year, as planned.

Even if there are no cases of polio by year’s end, several obstacles remain. One revives the old conflict between Albert Sabin and Jonas Salk, the polio vaccine pioneers who dueled each other for decades. The simple-to-use oral vaccine that is the cornerstone of the eradication program contains live, weakened strains of poliovirus that occasionally mutate and regain their ability to cause disease. Developed by Sabin, this vaccine will continue to reintroduce poliovirus to the human population as long as it remains in use. The Salk vaccine, which uses killed virus, does not have this drawback, but it must be injected, and that makes it more difficult and costly to deliver. Although plans call for the world to abandon the live vaccine once wild poliovirus stops spreading, timing this precisely will be tricky and may require strategic use of the killed vaccine.

For now, the biggest challenge is not one of strategy. It is one of will. If humans wanted to stop the circulation of wild poliovirus, they could. Yet in a tragic irony, because vaccines work so well, many people discount their value. Why get a vaccine for polio, measles, or diphtheria if you rarely, if ever, see those diseases in your community? This ambivalence fertilizes antivaccination movements, which recently have swept through not just Nigeria but also the United States, Europe, and Australia. In each case, vaccine-preventable diseases have surged. It’s a bizarre dilemma. Medical science has a means to control nature, but in the final analysis, human nature decides our fate.

JON COHEN

COURTESY OF KELLOGG, HUBER, HANSEN, TODD & EVANS



Q&A WITH PETER HUBER

What Energy Crisis?

Peter Huber, an engineering professor turned telecommunications lawyer, doesn’t worry whence the next electron will come.

The idea that we’re running out of energy is deeply ingrained. How can it be so wrong? It’s very easy to get pessimistic about energy. Energy doesn’t just drop into your lap. The idea that demand will someday outpace supply seems obvious. But historically that hasn’t happened, and there’s good reason to suppose it won’t, because the factors that determine supply are overwhelmingly technological. And our technology improves very fast. Energy technology in particular is advancing faster than it ever has before.

Why is your new book, *The Bottomless Well*, subtitled *The Twilight of Fuel*? What matters isn’t the price of a barrel of oil. What matters is the price of getting mom and the kids to the soccer field. And that depends on two factors: the cost of the fuel and the cost of all the hardware, the technology, we wrap around it. Fuel is an ever diminishing part of the equation.

You mean efficiency saves the day? The opposite: efficiency always leads to more consumption, not less. Hybrid cars and semiconductor lights are very quickly going to be cloned into all sorts of new applications that don’t even exist today, and total energy consumption will rise, not fall. One highly energy-efficient Nintendo machine per teenager consumes far more power in the aggregate than one ENIAC per planet. SPENCER REISS

PROTOTYPE

Swell Pill

Drugmakers pack medicines into small pills so they'll slide easily down the throat, but pills' drawbacks—the uneven way they deliver drugs, their tendency to cause nausea and diarrhea—can be hard to swallow. Menlo Park, CA's Depomed has a solution: an aspirin-sized tablet that swells to the size of a nickel once it reaches the stomach. When the pill hits the stomach's gastric fluid, polymers mixed in with the drug puff up. The bloated tablet can't pass into the small intestine, so it stays in the stomach—where many drugs are best absorbed—for six to eight hours. This delay permits a slower, steadier release of the drug as the pill dissolves. It also keeps the drug out of the lower gastrointestinal tract, where medications such as antibiotics can kill normal bacteria, causing diarrhea and other side effects. Depomed expects its first product—containing metformin, a popular diabetes drug—to earn regulatory approval this year. Because it releases a steady dose of metformin over a longer period of time, the new pill will need to be taken only once a day, versus two to three times a day for the conventional version. Depomed is also testing pills aimed at treating urinary-tract infections, seizures, pain, and other conditions.

FACTS MACHINE

The DNA Defense

» In approximately **25 percent** of cases submitted to the FBI lab for DNA testing, the suspect's DNA does not match that found at a crime scene.

» DNA labs' casework increased **73 percent**, and their casework backlog increased **135 percent**, between 1997 and 2000.

» DNA evidence was first used to exonerate an innocent U.S. prisoner in 1989.

» From 1989 through 2003, **145 U.S. prisoners** were exonerated based on DNA evidence.

» **13** of the people exonerated by DNA evidence had been sentenced to death.

» Exonerated prisoners have spent, on average, more than **10 years** in prison.

» It costs an average of **$22,600** to keep one person in a U.S. prison for one year.

» Until October 2004, the maximum restitution for exonerated federal prisoners allowed by law was **$5,000**.

» **32 states** offer no restitution for exonerated prisoners aside from "gate money," which typically includes bus fare, clothing, and a nominal amount of cash.

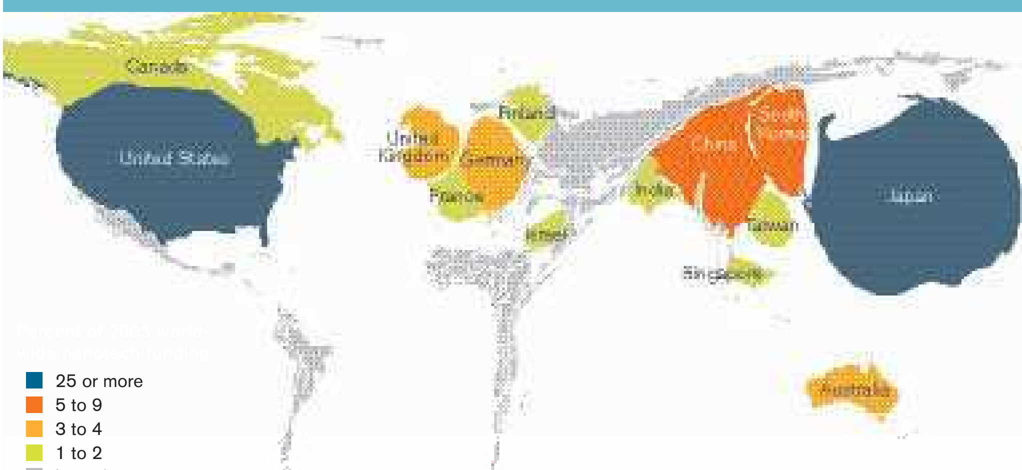
» Approximately **half** of convicts who receive postconviction DNA screening in an attempt to prove their innocence are in fact confirmed guilty.

SOURCES: UNIVERSITY OF MICHIGAN, U.S. DEPARTMENT OF JUSTICE, THE INNOCENCE PROJECT, NATIONAL INSTITUTE OF JUSTICE

TECHNOLOGY LANDSCAPE

Nano Investment

Just 14 countries accounted for nearly 90 percent of the $5.5 billion invested globally in nanotechnology in 2003. According to research firm Venture Analytics, Japan and the United States alone provide more than half of the world's nanotech funding. Worldwide, governments and corporations invest almost equally in the technology.



	2003 nanotech funding (in millions of dollars)	Percent from national government
Japan	1,610	50
U.S.	1,524	51
China	480	58
South Korea	280	71
Germany	218	54
Australia	193	48
U.K.	160	56
Taiwan	115	35
France	90	56
Israel	50	40
India	45	44
Finland	33	55
Canada	31	52
Singapore	30	50
Other	685	50
World total	**5,544**	**52**

SOURCE: VENTURE ANALYTICS, 2004

COURTESY OF RACHEL LIPSITZ/ATKINS + ASSOCIATES (PILL)

PROFILE

Cornell's Minister of Technology

W. Kent Fuchs bridges spirituality and technology

BERND AUERS

TO MANY PEOPLE, technology and religion are very different animals. Technology, after all, grows out of science and hard evidence; religion is based on faith. Yet in W. Kent Fuchs, dean of Cornell University's college of engineering, the two are intertwined. In the mid-1980s, before completing his PhD in electrical engineering at the University of Illinois, Fuchs (pronounced "fox") earned a master's degree at Trinity Evangelical Divinity School in Deerfield, IL. While a professor at Illinois, he moonlighted as a minister. This unusual second job taught him that community-building and communication are just as important in the development of new technologies as they are to the health of religious congregations.

Now in his third year as Cornell's engineering dean, Fuchs is taking the skills he honed in the pulpit into the technological arena. His facility as a communicator, for example, has helped him develop and garner support for an ambitious 10-year strategic plan that includes new research thrusts in biomedicine, sustainable energy, and complex systems. And Fuchs believes that Cornell's 12 engineering departments should engage with society at large, just as a church must engage its surrounding community. Last November, he signed an agreement at Tsinghua University in Beijing that is among the first to let U.S. and Chinese universities share students and intellectual property. "My faith really makes me understand the importance of taking technology and making it of use and benefit to society," he says. "Not just to improve the U.S. economy, but to promote global health, to bring up the standard of living worldwide."

Fuchs says that he is able to bridge the worlds of technology and religion effectively in part because he believes they have common goals: improving society and transcending human frailty. Religion helped give birth to the information age through the printing and dissemination of sacred scriptures and other texts. Now, says Fuchs, information technology is repaying the favor, improving people's understanding of world religions. Fuchs points out that advances in computing and digital communications have made religious texts available to larger audiences and have helped create new tools for analyzing languages in the Bible. Religious websites and chat rooms are exploding in popularity and are increasingly being used by churches for recruiting.

Of course, religious beliefs can also conflict with technological progress. "Technology is like religion," Fuchs says. "It can be of enormous good to society, or it can be misused." One possible example: the current debate over whether the U.S. government should fund research on embryonic stem cells. But on this issue, Fuchs sits squarely on the fence. Stem cells could potentially help society, he acknowledges, but there are "issues around unborn children and abortion." He says he hasn't confronted the problem yet in his work, and that he wants more information before he makes up his mind. "That debate is really healthy," he says, "as we look at what's really best for society and individuals."

Fuchs believes, though, that scientists should try to align the technologies they develop with their faith. That's especially important for biomedical fields like cloning that touch on issues of creation or immortality. Similar quandaries, albeit more speculative ones, arise in the information sciences. Take the idea, popularized by the futurist Ray Kurzweil, of downloading the contents of a person's brain onto a computer to preserve thoughts and memories for eternity. Fuchs is skeptical about the prospects for that sort of digital afterlife. "I don't believe we can emulate [personal immortality] with technology," he says.

But Fuchs is optimistic about his work and his role in society, in part because he believes that there is a better life to come after our physical bodies expire. Will there be technology in the afterlife? "I certainly hope so," he laughs. "I think there will even be colleges of engineering."

GREGORY T. HUANG

NEWS ANALYSIS

Microsoft Declares War on Spam

The once insular superpower is enlisting the help of allies

To: billg@microsoft.com
From: citibank
Subject: account suspend

NOTE! Citibank account suspend in process

To safeguard your account, we require you to sign on immediately. Please have your debit card number, User ID and Password at hand. Just click the link below.

ALEX NABAUM

YES, BILL GATES gets spam, just like everyone else. The difference between him and everyone else is that he can do something about it—really. If you roam around www.microsoft.com/spam, you'll find a war chest of information on the subject—backgrounders, press releases, primers on anti-spam technologies. There's even a personal update from Gates himself, written last June. "It's still a major problem," he tells us.

That inauspicious revelation aside, the maker of the world's most widely used in-boxes—think Hotmail, Outlook, Outlook Express, Exchange, MSN, and Entourage—has indeed proclaimed all-out war on the electronic scourge on productivity. Leading the offensive is a little-known cadre of some 50 spam fighters, the first of whom came out of Microsoft's research lab in March 2003. This Safety, Technology, and Strategy group has since helped bring lawsuits against some 100 spammers, and Microsoft claims that the e-mail-filtering technology the group has developed blocks several billion spam messages daily. Now Gates and company are beginning to deploy two new technologies that target the servers and e-mail programs of spammers themselves. "This pushes the battle to fight spam all the way out to the point e-mail is sent," says George Webb, business manager of the spam-busting team.

The Safety, Technology, and Strategy group is housed in Red West, a satellite campus about a mile from Microsoft's sprawling headquarters in Redmond, WA. The spam-fighting effort took root after a background paper written for Gates by Microsoft researchers outlined how new technological approaches could stem the growing tide of spam. At the time, various Microsoft product groups were independently pursuing their own anti-spam programs—and the new unit was chartered to unify those efforts and build a single technology that could be broadly deployed.

In a move that might seem at odds with Microsoft's image, the group also reached out to legislators, law enforcement, Internet service providers such as AOL, Yahoo, and Earthlink, and e-mail security firms

like Brightmail to help draft legislation, set standards, and launch consumer education efforts to fight spam. "We realized that we could not work in a vacuum, even a big vacuum like Microsoft," says Webb, and "we knew that it would take more than just technology."

Building on such coöperation, he says, the group joined with Microsoft's government affairs unit to help legislators shape the CAN-SPAM Act of 2003, which limits the transmission of unsolicited commercial e-mail. It also worked with the company's digital-integrity team, whose members include veterans of Interpol and U.S. law enforcement, to identify illegal spammers. As a result, the 100-odd legal actions include suits against five of the world's top 10 spammers.

On the technological front, the anti-spam group developed SmartScreen, a proprietary filtering technology based on statistical probabilities and machine learning that analyzes keywords, time sent, and other characteristics of e-mail to identify likely spam and siphon it off to a junk-mail folder like those now familiar to most e-mail users. Webb claims the amount of spam reaching Hotmail inboxes dropped 60 percent after SmartScreen's late-2003 introduction.

> In a recent survey, 60 million people said they had ordered products or services advertised via unsolicited e-mail.
>
> SOURCE: PEW INTERNET AND AMERICAN LIFE PROJECT FEBRUARY 2004 TRACKING SURVEY

Sender ID, one of the two new technologies Microsoft is readying for release, takes aim at two of the biggest problems largely missed by SmartScreen: spoofing and phishing. A spoof message pretends to be from a real source, such as a friend, colleague, or familiar organization. Phishing employs a spoof, such as the bogus Citibank message to Gates, to bait someone into revealing financial details or other key information. Sender ID compares the address of the server transmitting a message against a list of machines authorized to handle the sender's e-mail. Messages that don't line up can be flagged for filtration.

Computational proof, the second technology, is a more generic anti-spam weapon. The idea is to equip e-mail programs with software that forces any computer sending a message to work a little puzzle before its transmission is accepted. Each puzzle is unique—derived from elements of the message such as the time stamp or "from" line—and takes several seconds to compute. That's not a problem for servers sending normal volumes of e-mail, but it could really slow down a spammer trying to Uzi out millions of messages a day.

So will all this work? Others involved in the fight against spam credit Microsoft for its outreach and its technology, which will be incorporated into Hotmail, Outlook, and Exchange, beginning early this year with Hotmail. But their praise, predictably, is guarded. "Well, they're Microsoft. What they'd really like is for everybody to do things their way. But the spam problem is so awful that they're willing to work with other people for a broader solution," says John R. Levine, author of *The Internet for Dummies* and chair of the Internet Research Task Force's anti-spam research group.

Levine says Microsoft's struggle with its inner nature slowed the spam fight last year, when its initially broad patent claims on the Sender ID technology and onerous requirements for licensing the program caused standardization talks to break down. Since then, he says, Microsoft has narrowed its patent claims, "but they haven't fixed the license." And while the computational-puzzle technology is brilliant, he says, spammers' growing ability to activate tens of thousands of virus-hijacked "zombie" PCs at a time mitigates its potential effectiveness.

Still, Microsoft *is* Microsoft—and by dint of its ability to deploy its technologies to millions of customers, the company is raising the bar for spammers. In some situations, SmartScreen and other commercially available technologies can already block as much as 95 percent of spam. If Microsoft can effectively work with customers and rivals to create powerful blends of its own and other emerging technologies, the threat to productivity posed by spam could soon be a thing of the past.

Then Gates will finally be able to update his online spam update, with "it used to be a problem." **ROBERT BUDERI**

KIM KOMENICH/SAN FRANCISCO CHRONICLE/CORBIS

PROTOTYPE

Universal Flu Vaccine

A new influenza vaccine could protect against almost any strain of the virus, eliminating the need to create a new flu shot each year and the potential for shortages like the one faced by the United States last fall. Unlike current flu vaccines, which consist of inactivated virus and take months to manufacture, the new vaccine uses small snippets of viral DNA and could be made in only days or weeks. While DNA-based flu vaccines have been tested in the past, they have consistently proved less effective than inoculations of inactivated virus. A team at the Karolinska Institute in Stockholm, Sweden, increased the effectiveness of its DNA vaccine by adding an injection of tucaresol, a drug being tested in humans against sickle cell anemia and AIDS. In mice, the results were comparable to those that inactivated-virus jabs had produced in prior studies. A tucaresol-DNA combination should provide long-lasting protection against the flu in humans, say the researchers.

SOUNDBITE

"When we say al-Qaeda is a global ideology, this is where it exists—on the Internet. That, in itself, I find absolutely amazing."

—Michael Doran, Near East scholar and terrorism expert at Princeton University

(see p. 46)

ASIA KEPKA

Q&A WITH ANGELA BELCHER

Guiding the Evolution of Things

From engineered viruses, novel materials

COULD THE TINIEST organisms be the foundries of the future? Angela Belcher thinks so. The MIT materials scientist engineers viruses to manipulate compounds at the molecular level. A 2004 MacArthur Fellowship (a.k.a. "genius grant") winner, she's also a cofounder of Cambridge, MA's Cambrios Technologies, which applies her work to everything from lighting to microchip fabrication.

What do you do? We look at how nature processes materials and then evolve organisms to make new types of materials.

But you don't like being called a nanotechnologist? I'm a materials chemist who works on nanosize materials.

In fact you're a materials chemist who's engineering viruses to build computer chips. Are distinctions between conventional academic disciplines losing their meaning? You want to be an expert at some discipline of science or engineering. Then you integrate other things.

The legend is that you began by wondering how sea shells were made, while walking on the beach as a grad student at UC Santa Barbara. It's a nice story, but people have been studying the toughness and hardness of shells for fifty years.

So do abalones do nanotech? They do. The hardness and luster is a function of the very, very uniform structure of calcium carbonate, deposited a molecule at a time. That's also what makes pearls.

Why jump from that to something as complex as microchips? Chips are the dream. We have roughly thirty other shorter-term projects—magnetic storage materials, [solar cells] for energy-efficient lighting, flexible batteries.

The chip-making techniques you're talking about promise features a tenth the size being achieved with conventional methods. How close are you to something that actually works? We're making components right now, simple transistors. The next thing is to make useful architectures.

Your company describes its business as "directed-evolution technology." So the goal is something with potentially very broad application? It's a platform technology, yes. The aim is to work our way through the whole periodic table and be able to design materials of all kinds in a controlled way. My biggest goal is to have a DNA sequence that can code for the synthesis of any useful material.

But so far you have to use millions of viruses to find one or two that do something useful. Are there shortcuts? That's what we're working through now—what the rules are for how viruses interact with materials. But until we achieve that, we're still making progress through trial and error and a lot more genetic manipulation.

Presumably the answer is, design better organisms and you'll get better materials. Exactly. And we're not limited to viruses. We work on yeasts, too.

So a wholly new organism could create a wholly new material? We're working toward that, yes—new alloys, for instance.

Nanotech meets genetic engineering: there's a lot here to upset technophobes. We're not making dangerous materials. In fact, we're trying to reduce the amount of harmful materials going into the environment, not increase it.

Some people find "self-assembly" worrisome. I don't really understand why. So many things in the world self-assemble. Mix sodium and chlorine together, and it self-assembles to form a crystal. People often mix up "self-assembly" and "self-replication." Things aren't going to self-assemble out of control. It's like worrying about your table salt replicating out of control. It just won't happen. **SPENCER REISS**

STARTUP

So what are you reading these days?

Rojo Networks ensures we're all on the same page

THESE DAYS IT seems everyone's blogging. Combine this newest source of information with more traditional online news sources, and you could spend your whole day slogging through lists of bookmarked Web pages just to keep up. Rojo Networks is one of the latest of a bevy of startups trying to help Web users make better sense of this content explosion. The year-and-a-half-old startup's approach is to help users home in on the most relevant and interesting news and blogs by finding out what others in their online social networks are reading.

Rojo exploits a recent and growing phenomenon called RSS, for Really Simple Syndication. With RSS, an online publisher can format content so that users can extract and display it, along with content from other publishers, using "RSS aggregators." These personalized websites and dedicated reader programs let users view all the RSS "feeds" they subscribe to—complete with headlines, summaries, and links to original content—in one location.

San Francisco's Rojo is one of dozens of RSS aggregator companies. Like some of its competitors, Rojo has an RSS feed search function and gives readers the ability to flag stories they find important or interesting. But in enabling users to draw on the insights of friends, family, colleagues, and others in their social networks, Rojo departs from most of the competition. Rojo users can invite others to sign up for Rojo accounts; those accounts are linked, much like the accounts on the popular website Friendster. Rojo users can see what RSS feeds the members of their networks are reading and which stories they are flagging. Network popularity also affects the ranking of results when the user searches RSS feeds. "We all depend on our community for content discovery," says Chris Alden, Rojo's cofounder and CEO. "Any successful media service has to tap into that." [Disclosure: *Technology Review*'s editor in chief worked for Alden when he was CEO of *Red Herring*.]

As of press time, a limited number of invited users were testing Rojo's website, which was launched in October. The startup also hopes to strike deals with content providers to let them add RSS aggregation, search, and sharing to their own websites. Rojo closed its second round of venture capital financing in November.

Alden says Rojo is the first company to combine RSS aggregation with social networking, but it probably won't be the last. Rojo is one of a growing number of companies turning social networks into a tool for better managing and sharing online content. Of course, the makers of longer-standing RSS aggregators like Bloglines predictably point out that Rojo is missing a lot of features that their own services provide and charge that Rojo's website isn't easy or intuitive to use.

The company will have to deal with more fundamental questions, like whether people will build social networks at Rojo just to help them sort through RSS feeds, when they probably already maintain networks at places like Friendster. If not, Rojo will have to rely on partnerships with other websites, the approach taken by Eurekster, also out of San Francisco. Eurekster provides Friendster and other social-networking sites with a search engine that uses network data to improve the relevance of Web search results. "We believe people aren't going to want to invite their friends to all these different [social-networking sites]," says Grant Ryan, Eurekster's president and chairman. Since existing sites are consistently adding new services and features—and RSS sharing is one attractive candidate—Rojo may be better off working with them instead of trying to create its own site. CORIE LOK

KAI VERMEHR/EBOY.COM

Others in Really Simple Syndication

COMPANY	TOTAL FUNDING	INVESTOR(S)	FOCUS
FeedBurner	$1 million	Portage Venture Partners	Provide feed management services and tools to publishers
NewsGator	less than $10 million	Mobius Venture Capital	Software that allows users to read feeds in Microsoft Outlook
Pheedo	undisclosed	Fastlane Ventures	Help publishers and advertisers place and manage ads in feeds
Pluck	$10 million	Austin Ventures, Mayfield Fund	Software for reading feeds and searching the Web in Internet Explorer

SOURCES: COMPANY INFORMATION, VENTURE ECONOMICS

NEWS ANALYSIS

Logging On to Your Lawyer

Artificial intelligence, real justice?

CHRISTOPHER HARTING

MANUFACTURING, FINANCE, AND the communications industry have in the last decade all come to rely upon artificial intelligence. But there's one industry that continues to put up resistance: the legal profession. The idea of a machine making legal decisions was long considered by opponents to be dangerous and ethically untenable. That's about to change, says John Zeleznikow, a computer scientist at Victoria University in Melbourne, Australia. Zeleznikow believes AI is about to improve people's access to justice and massively reduce the costs of running legal services.

Joining forces with Andrew Stranieri at the University of Ballarat, also in Victoria, Zeleznikow launched startup JustSys to develop AI-based online legal systems that don't overstep the ethical line. Judges already use one program to assist them in the complicated and arcane process of sentencing criminals. Divorce lawyers and mediators are using another, called SplitUp, to help couples settle property disputes without resorting to the courts.

But by far the most widely used program is GetAid, which assesses applicants' entitlement to legal aid. Historically, assessment has consumed a significant portion of Victoria Legal Aid's operational budget. Using something like GetAid frees lawyers and paralegals from the task so they can spend their time actually representing people, says Domenico Calabro, a Victoria Legal Aid lawyer. The system is due for commercial launch in the next month or so, and according to Calabro, the Australian authorities are considering whether to roll it out nationally.

Of course, lawyers and judges have been using specialized software tools for years. But what sets these AI-based programs apart is their ability to draw inferences from past cases and predict how the courts are likely to interpret new cases.

It's not the first time researchers have tried to develop such tools. In the 1980s, an AI-based program was developed at Imperial College London to interpret an immigration law called the British Nationality Act. Critics worried that the system, which was never implemented, could be used to entirely bypass lawyers—and the protections they afford. "Parliament produces statutes, but these are reïnterpreted by the legal profession," says Blay Whitby, an AI expert at the University of Sussex in England. Taking lawyers out of the loop could allow a government too much control over the interpretation of laws, he says.

Zeleznikow believes his software overcomes these kinds of problems by preserving human participation and by limiting the system's authority. GetAid, for example, cannot reject applicants; it can only approve them. All other applications are referred to human officers for reassessment. Similarly, a judge can use the Sentencing Information System to help examine trends in other judges' decisions, but ultimately, the sentence has to come from the judge. "They are still making the decision, but their decision is far more visible," says Stranieri. This, in turn, encourages greater consistency in sentencing, he says.

Sussex's Whitby is cynical about the legal profession's opposition to AI. Loss of income and an irrational suspicion of technology are at least partly responsible, he says. "They might also have to sharpen up their arguments and practices to deal with machine-advised clients," he says. With a new generation of techno-savvy lawyers, of course, attitudes may change within the legal profession.

In fact, this already appears to be happening, says Stuart Forsyth, a consultant for the American Bar Association's Futures Committee. Forsyth sees a willingness, at least among U.S. lawmakers, to embrace technology. The reason, he says, is likely the growing trend toward self-representation in U.S. courts. "In domestic dispute cases it's well over 50 percent, and in others it's as high as 80 percent," he says. This is worrying, he says, because if people are going into court with no legal skills, they may be getting short shrift. The bottom line: artificial justice may be better than no justice at all. **DUNCAN GRAHAM-ROWE**

75 YEARS AGO IN TECHNOLOGY REVIEW

Purblind Cities

Already The Review has many times asseverated that the adoption by American cities of comprehensive and intelligent regional plans, as well as methods for noise and smoke abatement, is imperative if we are to have metropolitan areas free from the chaotic and choking congestion, the nerve-wracking roar, and the filth that is beginning to prevail. The immediate need is that the ordinary citizens as well as the office-holders recognize the acuteness of the problem, for its solution depends upon the coöperation of every component of a metropolitan community. Professional city planners, architects, physicians, and social critics have long perceived the need and shouted about it. In books, speeches, and the press their pleas are growing into a crescendo that can hardly fail to move municipal constituencies to action.

(February 1930, p. 200)

New Zealand: Green Haven for Biotech?

The island nation may have found a way to calm both sides in the debate over genetically modified organisms.

The life science industries need a new prescription. Pharmaceutical makers, who say their high drug prices are necessitated by the huge cost of developing new medicines, are on the defensive as U.S. politicians talk about price controls and even patent reforms favoring makers of generic drugs. But if there is one group feeling particularly besieged, it's the biotechnology companies applying genetic engineering to crops and farm animals. Trade conflicts between Europe and the United States over genetically modified organisms (GMOs) are now spreading to Brazil, India, and China. Despite the potential of so-called agbio technology to produce new medicines and conquer malnutrition, rules governing firms developing GMOs are frequently ill defined, difficult to implement, and hotly contested. For most, wooing investors has become exceedingly difficult.

It's not a lack of promise that's getting in the way. Production of genetically modified crops jumped 20 percent between 2003 and 2004. Genetically modified plants, which include corn, wheat, cotton, tobacco, rapeseed, soybeans, tomatoes, rice, potatoes, and poplar trees, are engineered to produce higher yields, grow in harsher soil conditions, and require fewer herbicide and pesticide treatments. The milk from genetically modified cows, goats, sheep, and rabbits is being used to produce therapeutic proteins for hard-to-treat conditions such as antithrombin deficiency, which leaves sufferers vulnerable to deep-vein thrombosis. But given the chaotic state of regulation and public opinion, developing a new agbio product has become a gamble.

New Zealand, of all places, may have found a solution, proving once again that the best ideas pop up where they are least expected. This nation's four million inhabitants form arguably the most politically and environmentally correct society on the planet—and one might think, therefore, among the most staunchly anti-GMO. New Zealand is a nuclear-free zone. Its two main islands have a small but politically powerful population of indigenous Maori, who are newly emboldened and empowered after generations of repression, and who consider plants and animals to be their kinfolk. The Green Party enjoys enormous influence in government. The country is as famous for the verdant, rolling hills of the north island and the rugged alps of the south island as it is for its high-quality, disease-free farm products—chiefly dairy, beef, and lamb. New Zealand's economy is far more dependent on agriculture than those of its Western peers; farming accounts for 4.8 percent of the country's gross domestic product, compared to .9 percent in the United Kingdom and 1.4 percent in the United States. So it's not surprising that until recently, New Zealand was on its guard against anything that might sully its pristine image. Only four years ago, the country essentially told Monsanto that its biotech wheat was not welcome there.

New Zealand

Population: 3.99 million
2004 exports: $15.86 billion (largely dairy, meat, wood, fish, and machinery)
The case: Genetically engineered crops and animals will never deliver on their promise to offer safe ways of increasing productivity without a regulatory framework that all sides trust. Rules recently adopted in New Zealand could show the way.

But against long political odds and at considerable risk to the country's clean-green image, New Zealand's parliament concluded just over a year ago that the potential rewards from GMOs outweigh the risks. To keep its economy growing, lawmakers reasoned, the nation would need to find ways to produce more (and more valuable) dairy and forest products on less and less acreage. The key would be, not to turn away from GMO technologies, but rather to manage them wisely with a transparent, enforceable, publicly accessible, and scientifically robust regulatory framework. This framework, enacted in October 2003, gives New Zealanders more power to participate in the approval process for local GMO research and development projects than any other people in the world. At the same time, the laws protect biotech firms that meet the new standards against litigation, a problem that has been a major damper on GMO projects in other countries. Environmen-

ANDY ROGERS/AP PHOTO

talists still worry that New Zealand's protocols aren't fail-safe, and biotech firms complain that they are too costly and time consuming. But both sides agree that the country has made a start. In fact, New Zealand's GMO regulations are now considered among the world's most functional. Says one veteran biotech investor in San Francisco, "Now anybody who is investing in agbio* is paying attention to New Zealand."

"Pressing On, but with Care"

By some accounts, trade disputes between the United States and Europe over genetically modified organisms have cost American farmers, packaged-food processors, and life science companies billions of dollars over the past five years. New Zealand's early experiences with the genetic engineering of crops and animals were no less tumultuous. One of the country's first responses to the prospect of genetically engineered crops and animals was the 1996 Hazardous Substances and New Organisms Act, which established a new regulatory agency called the Environmental Risk Management Authority (ERMA).

A "public storm" had erupted as soon as the government began to accept applications for field trials of genetically modified organisms in the mid-1990s, according to Bas Walker, ERMA's chief executive. But the new regulations' mechanisms for public input doubled the volume of the criticisms. "Every proposal became a cause célèbre," says Walker. By 2000, groups such as the Green Party and the Sustainability Council of New Zealand and Maori activists and politicians were calling for a moratorium on GMO research, development, and field releases until the government could be sure it was managing the technology properly.

The government and the biotech industry agreed to a voluntary moratorium and Parliament convened a royal commission to study GMOs. In late 2001, the commission came back with its answer: genetically modifying animals and plants would be fraught with risks, but could also be vital to New Zealand's economic future, which, the commission noted, will depend heavily on agricultural innovation. The message was "Press on, but with care," says one commission member who preferred not to be named because of the political sensitivity still surrounding the issue.

In October 2003, Parliament allowed a moratorium on GMO commercial releases to expire. But at the same time, it amended regulations to include an array of new checks and balances designed to ensure that GMO research was done safely but also openly, and with respect for Maori cultural traditions.

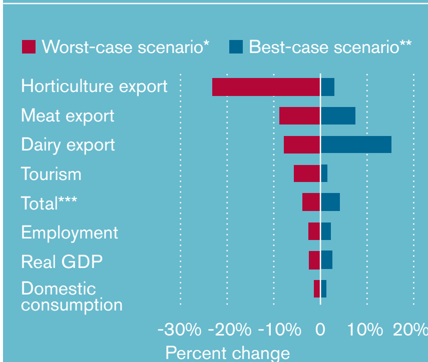
For the biotechnology industry, one attractive aspect of the new regulations is their unique civil-liability provisions. In many countries, anti-biotech groups have stalled field tests of genetically engineered crops by filing lawsuits or winning injunctions based on claims of possible harm to the environment. In New Zealand, legal action doesn't paralyze GMO research and development. But government protection must be earned: the public is invited to voice its concerns about a GMO research or development project before a company's application is accepted, and the government must address these concerns before an application is granted. Government examiners make spot checks, and companies must file annual updates to ensure compliance. General descriptions of these projects and status reports are publicly available on the ERMA website. No other country ensures comparable levels of public input, government oversight, or transparency.

Life with ERMA

Several field trials of genetically modified trees, onions, and dairy cows have been approved, and the reaction from the country's traditional GMO critics has been relative silence. One issue flaring up in other countries—the potential threat to communities located near waste disposal sites for genetically engineered animals and plants—has not become an issue in New Zealand. That's partly because ERMA's regulations call for agbio companies to observe local traditions. For example, near Mangakino, in the South Waikato region of New Zealand's northern island, Whakamaru Farms destroyed 3,000 genetically engineered sheep left by PPL Therapeutics, which had sold its land and buildings to Whakamaru. (PPL had gone out of business, and destroying the sheep was the only way to avoid the risk of losing track of which animals were genetically engineered.) Whakamaru incinerated the sheep, as Maori tradition demanded, rather than burying them. "We live in a small community where everybody knows their neighbor," says company director George Mitchell. "If you look at GMO protests around the world, you'll see that most of them are very grass roots and community based. Nobody in the community is protesting our presence. That,

Kiwi Export Fears

Based on consumer surveys, the New Zealand government projected that planting GMOs could harm produce exports or enhance dairy and meat exports.

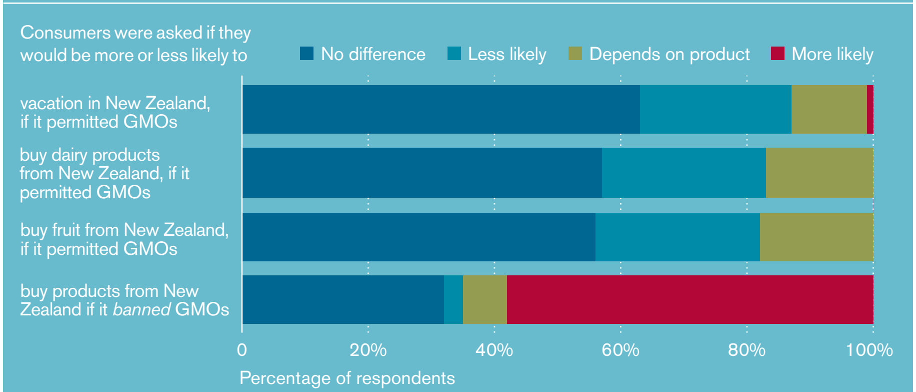


*LOWER EXPORT DEMAND WITHOUT PRODUCTIVITY INCREASE. **LIKELY PRODUCTIVITY INCREASE WITHOUT ANY DEMAND CONTRACTION. ***INCLUDING OTHERS NOT SHOWN. SOURCE: NEW ZEALAND MINISTRY FOR THE ENVIRONMENT

*WWW.TECHNOLOGYREVIEW.COM How can other countries balance GMO safety concerns with business needs? Experts weigh in; keyword GMO.

Consumers Tolerate GMOs

In a survey of American, Canadian, and Australian consumers, respondents preferred that New Zealand not grow GMOs; but most also reported that if New Zealand did grow GMOs, it would make no difference to their consumption patterns.



SOURCE: NEW ZEALAND MINISTRY FOR THE ENVIRONMENT

and the fact that, long-term, we think this technology and protocol put us in a very nice competitive position, was what led us to buy this operation ourselves."

In Mosgiel, the heart of New Zealand's dairy region, Maoris follow a very different ritual around the death of animals. "We have to bury [cow carcasses] in keeping with local Maori custom," says Jimmy Suttie, general manager of applied biotechnologies at AgResearch. "It's these kind of things in our regulatory regime that are arduous for companies, but ultimately allow us to move forward without worry of lawsuits or other interruptions created by those who might want to stall our operations."

Few New Zealanders consider the regulations perfect, and they will likely undergo more revisions. The official position of the Sustainability Council of New Zealand is that New Zealand should be GMO-free for at least the next few years. Now that the government has decided otherwise, however, Simon Terry, director of the council, says the regulations are an acceptable starting point for passing better laws in the future. The council's assessments, he notes, take into account a full range of potential effects—health, environmental, economic, and social. "In the end, [regulators] can only approve an application if there is considered to be a net benefit to the nation."

One weakness of ERMA, say some in the biotech industry, is the lack of a standardized procedure for applications and compliance reviews. The law gives ERMA great flexibility to seek outside advice in complex cases. But that confounds companies trying to create predictable and efficient regulatory and compliance systems. "We've been doing field trials on radiata pine, which is a very important plant to this country's future," says Christian Walter of Forest Research, an agbio company in Rotorua. "It hasn't been easy. Neither our funding agents nor our anti-GMO opponents realize just what we have to do now before we can even think about research outside of the lab." Walter has excellent environmentalist credentials: he was a cofounder of Greenpeace in Germany. But old notions, he says, die hard. "I don't know when we'll get to a point where we decide to apply for a [full open-space] release application. There's still a lot of public ambivalence to this because nobody has ever created a plantation of [GM trees] in a New Zealand forest before.

"The only way the world will ever learn the real risks and rewards [of GM trees] is to put them out into a real-world setting, with precautions and oversight. We've got a lot of new safety mechanisms and a history of forestry innovation in New Zealand. The world is going to be looking at us to deliver a lot of [GM forest] insights soon. If we don't deliver, we've got nobody to blame but ourselves."

The Kiwi Gold Standard

It's too soon to know whether New Zealand's new regulations will pay long-term dividends. In the short run, at least, the feared international backlash against exports from New Zealand—now that the country has cleared the way for GM dairy, meats, and forest products—has not materialized. New Zealand expects continuing growth in global demand for its leading exports, forest and dairy products.

Consultants to government regulators in Europe, Canada, Australia, and Brazil say New Zealand's GMO protocol will likely be imitated to buttress the evolving regulations in these countries in the near future. "New Zealand's [GMO] approach is clearly the gold standard now," says one government consultant who wished to remain anonymous.

That could eventually bring business and jobs to New Zealand and, which after years in the shadows of Australia and Singapore, is starting to gain a reputation as a regional biotechnology haven. "It was only a couple of years ago that we were all ready to write off New Zealand," says to the San Francisco agbio investor who requested anonymity. But leading New Zealand agbio firms like Forest Research, AgResearch, and Whakamaru Farms are pushing forward with long bottled-up plans for R&D projects. And European and American investors say they have noticed a distinct increase in business proposals from New Zealand.

At the same time, many foreign companies developing GMOs will establish branch operations in New Zealand, predicts Jeffrey Turner, CEO of Canadian biotech company Nexia. "There could be a huge advantage for some companies to develop their technologies in New Zealand now, because the country's regulatory protocol is seen as extremely robust and politically legitimate."

That suits the population of New Zealand just fine. Pete Hodgson, a member of the country's parliament from Dunedin North, feels the mere existence of ERMA and the new GMO regulations should prove to the world that industrial biotech and concern for the environment, society, and indigenous cultures need not be fundamentally incompatible. New Zealand's recent effort, says Hodgson, "is proof that there is no such thing as irreconcilable differences." STEPHAN HERRERA

Intel's Centrino Solution

The old mantra for PC chip makers—faster is better—is breaking down. Can "platformization" take its place?

Before 1991, only a few computer aficionados cared which company made the microprocessors inside their PCs, or how fast those processors ran. But then came "Intel Inside," the chip maker's ingenious campaign to market directly to consumers. The advertising crusade not only trained PC buyers to look for the Intel sticker on new desktops and laptops; it made them feel old-fashioned if they didn't have the latest, fastest edition in the 486 or Pentium series of chips. And Intel prospered, cementing its lead over rivals such as Advanced Micro Devices. An impressive 82 percent of PCs shipped globally in the third quarter of 2004 contained Intel microprocessors.

But computing is changing in ways that are forcing the company to stretch beyond its traditional talent for making and marketing faster and faster microprocessors. For one thing, there's a ceiling on the number of transistors that can work side by side on a single chip without overheating, and Intel and its competitors are already banging up against it. That's leading to more efficient designs that use multiple processors and get tasks done faster by breaking them up, rather than by making each processor do more operations per second. At the same time, people are taking advantage of innovations like wireless broadband to use their computers in new ways. If your laptop's main function is to keep you in touch with the office from any airport lounge or conference hall, you'd probably prefer an energy-efficient processor that gives you an extra hour of battery life to one that can run your PowerPoint animations faster.

PAULA BRONSTEIN/GETTY IMAGES

Intel

Headquarters: Santa Clara, CA
Revenue, 2004: $33.7 billion (estimated)
Revenue, 2003: $30.1 billion

The case: With engineers approaching practical limits on chip speed, and PC users learning to prize mobility over swiftness, microchip makers like Intel are being forced to rethink their strengths. Intel's Centrino mobile-computing campaign was the first sign that the company is transforming itself from a manufacturer of ever faster microprocessors into a provider of broad "platforms" of computing and wireless technologies.

Intel engineers saw these trends coming, and shortly after the millennium they started designing a cooler-running, more power-efficient processor called the Pentium M. When wireless Internet standards began to catch on with consumers around 2002, Intel decided to combine the Pentium M, a Wi-Fi radio, and a new low-power chipset—a group of memory and graphics chips supporting the CPU—into a package called Centrino. Since the launch of Centrino in March 2003, Intel has captured a respectable 11 percent of the market for wireless networking *(see "A Newcomer to Wireless," p. 32)*, up from zero prior to Centrino.

Centrino can be viewed as a case of good timing (Wi-Fi gained popularity just as Intel was looking for ways to make laptops and notebooks more useful) or as a brilliant encore to "Intel Inside." But executives say the project's real significance lies elsewhere. With Centrino, the company set itself a threefold challenge: to build on the strengths of formerly separate Intel products such as microprocessors and wireless networking cards by tailoring them to work in unison; to coördinate the work of the divisions responsible for these components, so they could be launched simultaneously under a single Intel brand; and to convince PC manufacturers and consumers that they still need Intel technology in a market where mobility and communications, rather than simple computing speed, are paramount.

Incoming CEO Paul Otellini and others—who apologize for not coming up with a more elegant term—call their new philosophy "platformization." They say sequels to Centrino are coming in areas such as home digital entertainment and enterprise computing. Platformization "means the convergence of computing and communications," says chief technology officer Patrick Gelsinger. "But it's far more than that, because it changes every aspect of what we do."

The first signs of change came early in this decade, when designers at Intel admitted to themselves that "eventually the microprocessor would hit a power wall," says Mooly Eden, then vice president of Intel's Mobile Platforms Group and the man most credited with conceiving and executing the Centrino project. Making computers more portable meant reducing the CPU's power consumption and heat emissions, which in turn meant sacrificing some clock speed. The first step in that direction was the Pentium M, which used less power and generated less waste heat than its predecessor, the Pentium III, but ran at only 65 to 85 percent of the Pentium III's top clock speed.

The second step: the so-called 855 chipset surrounding the Pentium M, which also used less power and was small enough to squeeze into a notebook-sized computer. As a pair, the Pentium M and the 855 chipset would have allowed computer manufacturers to sell laptops that

stayed on for more than an hour longer, without any improvements in battery capacity (which remains the biggest laggard in mobile computing technology).

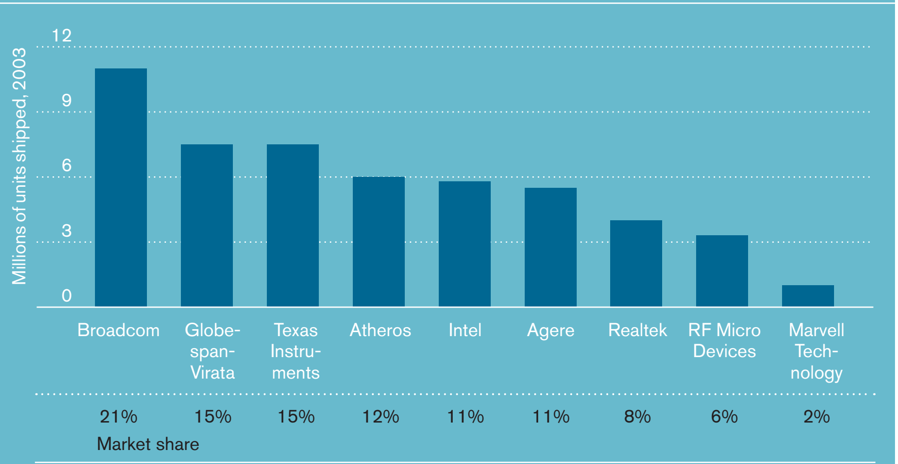
But then came a third development. As Eden puts it, "Now that you can go away from your desk for five hours, you must make sure you are still connected." Wi-Fi was an almost ideal way to do that: it provided communication at DSL speeds and allowed users to connect to the Internet from anywhere within a 100-meter radius of a central base station (or 400 meters outdoors). At the time, connecting to a Wi-Fi network meant buying a separate, removable network card from a company such as Broadcom. But Eden and his colleagues realized that if they could build Wi-Fi chips small enough to fit inside a laptop, Intel would have all of the components needed to make laptops into mobile workplaces. So even though the three components of Centrino "were not conceived as a 'platform' from day one," says Eden, the idea of cobranding them took hold quickly. "Paul Otellini was very strong about going in this direction, and there was no argument between Paul, Craig, and Andy," Eden says, referring to Craig Barrett, the company's sitting CEO, and Andy Grove, its cofounder and chairman.

All three men, in fact, believed Intel had to enter the next decade of computing with more to offer than raw computing power. Platforms like Centrino would provide an incentive for Intel's customers—the companies that actually sell Pentium laptops and notebooks—to purchase more Intel components. But more importantly, they would inspire computer owners to find new uses for their PCs.

Still, committing to Centrino was a gutsy decision. For one thing, Intel wasn't a platforms company. Microprocessors, chipsets, and wireless components were (and are) made by independent divisions, each with its own vice president responsible for the division's bottom line. The divisions weren't accustomed to meeting schedules imposed from above, and the Centrino project as a whole could proceed only as fast as whichever team was having the most technical trouble, says Eden. "I cannot think of a minute where there wasn't a problem of some kind," says Eden. "I would not say people resisted it. But if I hadn't had the total endorsement of the executives, I don't believe we could have met the schedule or had this success."

A Newcomer to Wireless

In just the last three quarters of 2003, Intel managed to grab an 11 percent share of the market for Wi-Fi chipsets. And investment bank Piper Jaffray estimates that, in 2004, Intel almost doubled its share of this rapidly growing market.



SOURCE: IDC AND PIPER JAFFRAY

Intel also knew that Centrino would be seen as a stretch—or even an intrusion—by some of its customers. "There were very serious questions asked by some of the manufacturers," says Gelsinger. They wanted to know whether a microchip company understood how to build radios, and whether Intel's growing share of the innards of their computers would overshadow their own brands. Intel had to "paddle like crazy" to get mobile-PC manufacturers to buy into Centrino before the March 2003 brand launch, says Gelsinger.

Intel's final challenge was making sure there would be places where mobile-computer owners could actually use the technology. "To really make the Wi-Fi aspect work, you can't just give people a PC," says Mike Hoefflinger, Intel's director of comarketing. "There has to be something at the other end." A key part of Intel's strategy was to blanket high-traffic locales with enough Centrino-branded hot spots that consumers would be persuaded to buy Centrino laptops. So Hoefflinger led an effort to install Centrino-certified Wi-Fi base stations in hundreds of hotels, cafés, and airport clubs, each prominently displaying the Centrino logo.

By most measures, Centrino is succeeding. Computer buyers have come to expect wireless local-area networking as a standard feature of new laptops and notebooks. And coming not far behind Wi-Fi is WiMax, a new high-speed wireless networking standard with enough range to cover entire cities *(see "Why WiMax?" November 2004, p. 20)*. Gelsinger says Intel will launch a new WiMax-capable version* of Centrino in 2006.

Centrino "marked the beginning of a major change in the way Intel brings value to the market," says Otellini. That means you shouldn't be surprised if the PC or laptop you're buying two or three years from now includes new Intel components that beam video and music files to your entertainment center or communicate wirelessly with Intel chips in your climate control system and your car. For just as computing spread from the mainframe to the personal computer almost 25 years ago, it's now spreading from the PC to the larger environment. Equipment makers who adapt to this transition, rather than resisting it, are much more likely to be around 25 years from now. With Centrino as "the playbook and the gold standard" for future platformization projects, to quote Hoefflinger, Intel may have the inside track. **WADE ROUSH**

* **WWW.TECHNOLOGYREVIEW.COM** What are other chip companies doing to compete with Intel? For analysts' answers, enter keyword **Intel**.

Two Sides of Outsourcing

Indian outsourcing giants like Infosys are spawning innovators like Ittiam

WITH SO MANY startup founders, CTOs, high-level engineers, and venture capitalists in Silicon Valley tracing their roots to India, why doesn't India itself boast a booming high-tech innovation sector? One reason, of course, is that many of the best-trained Indian engineers still find it more exciting to work in the United States and other Western nations. But another, more controversial reason could be the type of business that *is* booming in India: information technology outsourcing. Some analysts worry that information technology professionals in India are too busy serving their well-paying foreign clients to risk time or capital on developing their own products for the Indian or U.S. markets*.

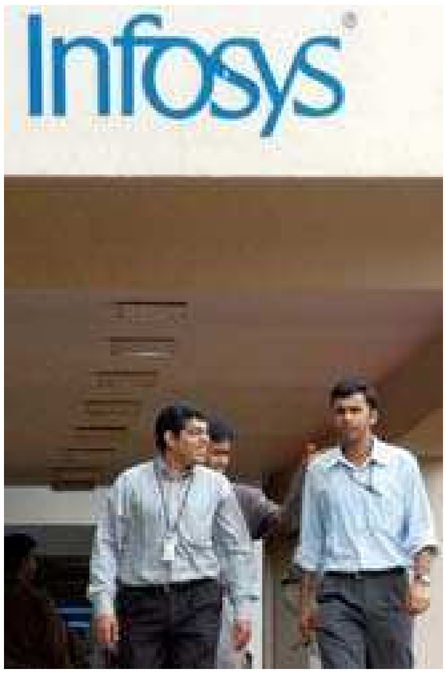
But the impact of outsourcing on indigenous innovation may not be so clear cut, as is shown by the experiences of two very different Indian companies, Infosys Technologies and Ittiam Systems. Big outsourcing providers like Infosys may not be fountains of innovation, but their presence will have—in fact, is already having—trickle-down effects. Outsourcing, many Indians argue, is training India's next generation of tech entrepreneurs.

Infosys Technologies, India's third-largest IT services company, was founded in 1981 to design, develop, and maintain software for U.S. corporate clients in banking, manufacturing, and telecommunications. In the late 1980s, when business was slow, Infosys turned to creating proprietary banking software that is still used today by about 70 percent of Indian banks. But after the Indian government loosened economic controls in 1991, the software services industry took off, and in the mid-1990s Infosys decided to drop further product development. "We did not want to conflict with our clients," says Kris Gopalakrishnan, Infosys's cofounder and chief operating officer. Infosys's services strategy has been enormously successful; the company's revenues have climbed by 30 to 40 percent since 2001. But now, most of the intellectual property it generates goes back to its clients.

But outsourcing can have indirect benefits. Take Ittiam Systems. A crew of former Texas Instruments (TI) employees—led by Srini Rajam, the former managing director of TI India and now Ittiam's CEO—founded the startup in 2001 to make better and cheaper digital signal-processing systems. The company secured $11.5 million in venture capital financing and by 2004 was earning profits of $1 million annually. Rajam, who worked for the giant Indian outsourcing firm Wipro Technologies before joining TI's India division, sees himself and his company as a child of the outsourcing phenomenon. "Outsourcing will help innovation," says Rajam. "It gives people confidence and experience"—not to mention the high salaries that free them to take risks on new ventures.

Indeed, Ittiam isn't the only example. Alumni of outsourcing companies like Wipro have launched dozens of startups in India, a few of them funded by JumpStartUp, a small venture capital firm based in Bangalore and Santa Clara, CA. One explanation for this trend, says JumpStartUp cofounder Sanjay Anandaram—himself a former Wipro employee—is that skilled and experienced Indians are returning home from abroad to provide leadership. Another is that people who've worked for Indian outsourcing firms serving multinational clients gain critical experience managing global operations.

But perhaps most important is a gradual change in attitudes in a culture where entrepreneurs were once seen as loners who couldn't hold down regular jobs, and business failure was traditionally equated with personal failure. Today "a startup is no longer viewed as a no-no," says Rajam. "It is in fact viewed very positively." At least some of this change can be credited to outsourcing, says Ashish Arora, a professor of economics and public policy at Carnegie Mellon University. "If India has any kind of successful product development, it will be because of the success of the software services sector." CORIE LOK



KENNETH EDWARD/BIOGRAFX/PHOTORESEARCHERS, INC.

Infosys Technologies
Headquarters: Bangalore, India
Revenues, 2004: $1.06 billion

Ittiam Systems
Headquarters: Bangalore, India
Revenues, 2004: $4.78 million

The case: Indian firms performing services and R&D for companies in the U.S. and elsewhere will never become product innovators themselves—but they are nonetheless incubating the country's next generation of technology entrepreneurs.

* WWW.TECHNOLOGYREVIEW.COM Is growth in India's IT sector a threat to U.S. competitiveness? For an economic analysis, enter keyword **India**.

Technology Can Fix U.S. Intelligence

The intelligence reform bill evaded real reform

David Rothkopf is chairman of Intellibridge, which provides intelligence and analysis for the government, and author of the upcoming *Running the World: The Inside Story of the NSC and the Architects of American Power.*

JOHN RITTER

The recently enacted intelligence reform bill was the best Washington could do, probably. That's the bad news. The good news is that the marketplace knows that intelligence reform is much too important to be left to politicians and bureaucrats.

The new legislation seeks to improve intelligence coördination through the appointment of a new layer of management. This alone can be a formula for failure. However, the chances of real reform are poor for other reasons as well.

The U.S. intelligence bureaucracy remains, unfortunately, convoluted and full of conflicting interests. The government's answer to September 11 has been to create new bureaucracies: the office of the national intelligence director is only one example. The response to management failures and communications breakdowns has been to make the system more complex, not simpler. In fact, a number of the steps taken or proposed have not even been necessary. The United States already *has* legislation calling for centralized control of its intelligence community. It's called the National Security Act of 1947. The current administration failed to manage the system as it should have.

The real problems within the intelligence community are much deeper and more ingrained. One way a technology audience might view them is as a failure to build an effective knowledge management system to support U.S. government policymakers. That perspective reveals an abundance of obvious flaws. There is a government culture that values secrecy and hoards knowledge rather than sharing it with those who need it most. Secrecy is important, but while emerging technologies—like quantum encryption, which will prevent eavesdropping—make it ever easier to protect information you want to hold close, they should be used to increase, not decrease, opportunities for openness. One senior military commander told me that perhaps 95 percent of what is now deemed secret is available via open sources, thanks to the Internet. Unnecessary secrecy costs billions and impedes the flow of vital information. It is also an exercise in futility. I've seen instances where Web-harvested information was received by the government and immediately classified.

As detrimental are the cultural biases institutionalized through a system of "stovepipes" that forces information to go up one management chain, across at the top, and down another before it can get to the people who need it the most. Furthermore, information producers within the intelligence community have too much control over who gets to see what—when every other new knowledge-based system in the world is being designed otherwise.

It is well within our power to create a flatter, more distributed knowledge management system that makes all data within the government available to users in real time regardless of agency affiliation, simply based on privileges assigned to them. But we don't have it yet.

Nonetheless, the existing system can be enhanced via a few key steps. Unbelievably, many in the national-security community don't have full access to the Web—because counterintelligence specialists worry that that would permit spies to hack into U.S. systems. Furthermore, much of what is out there is uninterpretable even to those who see it: the United States lacks specialized analysts, and those it does have don't have the linguistic skill to translate important data. But outsourcing the analysis and translation of open-source information to the private sector would enhance U.S. capabilities. In addition, the advent of the Semantic Web (which adds definition tags to information in Web pages so that computers can interact more productively) will further empower end users of information and make the Web a much more efficient tool.

If the government stopped spending billions producing what was already available for free or at low cost on the Web, then it could devote more money to the new technologies that will truly transform intelligence. These include everything from unmanned reconnaissance vehicles to the long-envisioned ubiquitous-sensing networks that deploy vast quantities of microsensors to capture live data. Learning to better massage, intelligently search, interpret, and use the resulting information and to get good analysis to users is the ultimate challenge for U.S. intelligence—not adding new bosses to the system.

Getting intelligence to the field in real time and moving analysts closer to end users—and out of the echo chambers of intelligence institutions—are achievable ends. It is the larger marketplace and technological innovators like the readers of this magazine who will produce the intelligence reforms we urgently need—reforms that the recent bill, for all the fanfare around it, largely ignored. ■

DO YOU WANT TO LIVE FOREVER?

Aubrey de Grey thinks he knows how to **defeat aging.** He's brilliant, but is he nuts?

By Sherwin Nuland

PHOTOGRAPHS BY JAMES DAY

WANDERING THROUGH THE QUADRANGLES AND medieval bastions of learning at the University of Cambridge one overcast Sunday afternoon a few months ago, I found myself ruminating on how this venerable place had been a crucible for the scientific revolution that changed humankind's perceptions of itself and of the world. The notion of Cambridge as a source of grand transformative concepts was very much on my mind that day, because I had traveled to England to meet a contemporary Cantabrigian who aspires to a historical role similar to those enjoyed by Francis Bacon, Isaac Newton, and William Harvey. Aubrey David Nicholas Jasper de Grey is convinced that he has formulated the theoretical means by which human beings might live thousands of years—indefinitely, in fact.

Perhaps *theoretical* is too small a word. De Grey has mapped out his proposed course in such detail that he believes it may be possible for his objective to be achieved within as short a period as 25 years, in time for many readers of *Technology Review* to avail themselves of its formulations—and, not incidentally, in time for his 41-year-old self as well. Like Bacon, de Grey has never stationed him-

self at a laboratory bench to attempt a single hands-on experiment, at least not in human biology. He is without qualifications for that, and makes no pretensions to being anything other than what he is, a computer scientist who has taught himself natural science. Aubrey de Grey is a man of ideas, and he has set himself toward the goal of transforming the basis of what it means to be human.

For reasons that his memory cannot now retrieve, de Grey has been convinced since childhood that aging is, in his words, "something we need to fix." Having become interested in biology after marrying a geneticist in 1991, he began poring over texts, and autodidacted until he had mastered the subject. The more he learned, the more he became convinced that the postponement of death was a problem that could very well have real solutions and that he might be just the person to find them. As he reviewed the possible reasons why so little progress had been made in spite of the remarkable molecular and cellular discoveries of recent decades, he came to the conclusion that the problem might be far less difficult to solve than some thought; it seemed to him related to a factor too often brushed under the table when the motivations of scientists are discussed, namely the small likelihood of achieving promising results within the period required for academic advancement—careerism, in a word. As he puts it, "High-risk fields are not the most conducive to getting promoted quickly."

De Grey began reading the relevant literature in late 1995 and after only a few months had learned so much that he was able to explain previously unidentified influences affecting mutations in mitochondria, the intracellular structures that release energy from certain chemical processes necessary to cell function. Having contacted an expert in this area of research who told him that he had indeed made a new discovery, he published his first biological research paper in 1997, in the peer-reviewed journal *BioEssays* ("A Proposed Refinement of the Mitochondrial Free Radical Theory of Aging," de Grey, ADNJ, *BioEssays* 19(2)161–166, 1997). By July 2000, further assiduous application had brought him to what some have called his "eureka moment," the insight he speaks of as his realization that "aging could be described as a reasonably small set of accumulating and eventually pathogenic molecular and cellular changes in our bodies, each of which is potentially amenable to repair." This concept became the theme of all the theoretical investigation he would do from that moment on; it became the leitmotif of his life. He determined to approach longevity as what can only be called a problem in engineering. If it is possible to know all the components of the variety of processes that cause animal tissues to age, he reasoned, it might also be possible to design remedies for each of them.

All along the way, de Grey would be continually surprised at the relative ease with which the necessary knowledge could be mastered—or at least, the ease with which he himself could master it. Here I must issue a caveat, a variant of those seen in television commercials featuring daredevilish stunts: "Do not attempt this on your own. It is extremely hazardous and requires special abilities." For if you can take a single impression

Along the way, de Grey would be continually surprised at the relative ease with which the necessary knowledge could be mastered.

away from spending even a modicum of time with Aubrey de Grey, it is that he is the possessor of special abilities.

As he surveyed the literature, de Grey reached the conclusion that there are seven distinct ingredients in the aging process, and that emerging understanding of molecular biology shows promise of one day providing appropriate technologies by which each of them might be manipulated—"perturbed," in the jargon of biologists. He bases his certainty that there are only seven such factors on the fact that no new factor has been discovered in some twenty years, despite the flourishing state of research in the field known as biogerontology, the science of aging; his certainty that he is the man to lead the crusade for endless life is based on his conception that the qualification needed to accomplish it is the mindset he brings to the problem: the goal-driven orientation of an engineer rather than the curiosity-driven orientation of the basic scientists who have made and will continue to make the laboratory discoveries that he intends to employ. He sees himself as the applied scientist who will bring the benisons of molecular biology to practical use. In the analogous terminology often used by historians of medicine, he

is the clinician who will bring the laboratory to the bedside.

And so, in order to achieve his goal of transforming our society, de Grey has transformed himself. His "day job," as he calls it, is relatively modest; he is the computer support for a genetics research team, and his entire official working space occupies a corner of its small lab. And yet he has achieved international renown and more than a little notoriety in the field of aging, not only for the boldness of his theories, but also because of the forcefulness of his proselytizing on their behalf. His stature has become such that he is a factor to be dealt with in any serious discussion of the topic. De Grey has documented his contributions in the scientific literature, publishing scores of articles in an impressive array of journals, including those of the quality of *Trends in Biotechnology* and *Annals of the New York Academy of Sciences*, as well as contributing commentary and letters to other publications like *Science* and *Biogerontology*.

De Grey has been indefatigable as a missionary in his own cause, joining the appropriate professional societies and evangelizing in every medium available to him, including sponsoring his own international symposium. Though he and his ideas may be sui generis, he is hardly an isolated monkish figure content to harangue the heavens and desert winds with his lonely philosophy. In addition to everything else, he has a remarkable talent for organization and even for his own unique brand of fellowship. The sheer output of his pen and tongue is staggering, and every line of that bumper crop, whether intended for the most scientifically sophisticated or for the general reader, is delivered in the same linear, lucid, point-by-point style that characterizes all his writings on life prolongation. Like a skilled debater, he replies to arguments before they arise and hammers at his opposition with a forceful rhetoric that has just enough dismissiveness—and sometimes even castigation—to betray his impatience with stragglers in the march toward extreme longevity.

De Grey is a familiar figure at meetings of scientific societies, where he has earned the respect of many gerontologists and that new variety of theoreticians known as "futurists." Not only has his work put him at the forefront of a field that might best be called theoretical biogerontology, but he swims close enough to the mainstream that some of its foremost researchers have agreed to add their names to his papers and letters as coauthors, although they may not agree with the full range of his thinking. Among the most prominent are such highly regarded figures as Bruce Ames of the University of California and the University of Chicago's Leonid Gavrilov and S. Jay Olshansky. Their attitude toward de Grey is perhaps best expressed by Olshansky, who is a senior research scientist in epidemiology and biostatistics: "I'm a big fan of Aubrey; I love debating him. We need him. He challenges us and makes us expand our way of thinking. I disagree with his conclusions, but in science that's okay. That's what advances the field." De Grey has by his vigorous efforts brought together a cohort of responsible scientists who see just enough theoretical value in his work to justify not only their engagement but also their cautious encouragement. As Gregory Stock, a futurist of biologic technology currently at UCLA, pointed out to me, de Grey's proposals create scientific and public interest in every aspect of the biology of aging. Stock, too, has lent his name to several of de Grey's papers.

De Grey enjoys increasing fame as well. He is often called upon when journalists need a quote on antiaging science, and he has been the subject of profiles in publications as varied as *Fortune*, *Popular Science*, and London's *Daily Mail*. His tireless efforts at thrusting himself and his theories into the vanguard of a movement in pursuit of a goal of eternal fascination to the human mind have put him among the most prominent proponents of antiaging science in the world. His timing is perfect. As the baby boomers—perhaps the most determinedly self-improving (and self-absorbed) generation in history—are now approaching or have reached their early 60s, there is a plenitude of eager seekers after the death-defiant panaceas he promises. De Grey has become more than a man; he is a movement.

I should declare here that I have no desire to live beyond the life span that nature has granted to our species. For reasons that are pragmatic, scientific, demographic, economic, political, social, emotional, and secularly spiritual, I am committed to the notion that both individual fulfillment and the ecological balance of life on this planet are best served by dying when our inherent biology decrees that we do. I am equally committed to making that age as close to our biologically probable maximum of approximately 120 years as modern biomedicine can achieve, and also to efforts at decreasing and compressing the years of morbidity and disabilities now attendant on extreme old age. But I cannot imagine that the consequences of doing a single thing beyond these efforts will be anything but baleful, not only for each of us as an individual, but for every other living creature in our world. Another action I cannot imagine is enrolling myself—as de Grey has—with Alcor, the cryonics company that will, for a price, preserve a customer's brain or more until that hoped-for day when it can be brought back to some form of life.

With this worldview, is it any wonder that I would be intrigued by an Aubrey de Grey? What would it be like to come face to face with such a man? Not to debate him—a task for which, as a clinical surgeon, I would in any case be scientifically unqualified—but just to sound him out, to see how he behaves in an ordinary situation, to speak of my concerns and his responses—to take his measure. To me, his philosophies are outlandish. To him, mine would seem equally so.

With all of this in mind, I contacted de Grey via e-mail this past fall, and received a response that was both gracious and welcoming. Addressing me by first name, he not only had no hesitation in offering to give up the better part of two days to speak with me, but moreover suggested that we spend them close to the lubricating effects of invigorating fluids, as follows:

> *I hope you like a good English beer, as that is one of the main (open) secrets of my boundless energy as well as a good part of my intellectual creativity (or so I like to think...). A good plan (by which I mean a plan that has been well tested over the years!) is to meet at 11:00 A.M. Monday 18th in the Eagle, the most famous pub in Cambridge for a variety of reasons which I can point out to you. From there we may (weather permitting) be able to go punting on the Cam, an activity with which I fell in love at first sight on arriving here in 1982 and which all visitors seem to find unforgettable. We will be able to talk for as long as you like, and if there is reason to meet again on the Tuesday I can arrange that too.*

The message would prove to be characteristic, including its hint of immodesty. And in a similar vintage was his response

when I expressed hesitation about punting, based on friends' tales of falling into the Cam on a chilly autumnal day: "Evidently, your friends did it without expert guidance." As I learned, de Grey is not a man who allows himself to be less than expert at anything to which he decides to devote those prodigious energies so enthusiastically trumpeted in the e-mail, nor does he allow himself to hide his expertness under a bushel.

Of course, to conceive of oneself as the herald and instrument of the transformation of death and aging requires a supreme self-confidence, and de Grey is the most unabashedly self-confident of men. Soon after we met, this unexampled man told me that "One must have a somewhat inflated opinion of oneself" if success is to crown such great endeavors. "I have that!" he added emphatically. By the time he and I had said our good-byes after a total of 10 hours together over a period of two days, I was certain many would accept his self-estimate. Whether one chooses to believe that he is a brilliant and prophetic architect of futuristic biology or merely a misguided and nutty theorist, there can be no doubt about the astonishing magnitude of his intellect.

De Grey calls his program Strategies for Engineered Negligible Senescence, which permits him to say that it makes SENS to embark upon it. Here, in no particular order, follow his seven horsemen of death and the formulations for the breaking of each animal and its rider. (Those seeking more detailed information might wish to consult de Grey's website: www.gen.cam.ac.uk/sens/index.html.)

1. Loss and atrophy or degeneration of cells. This element of aging is particularly important in tissues where cells cannot replace themselves as they die, such as the heart and brain. De Grey would treat it primarily by the introduction of growth factors to stimulate cell division or by periodic transfusion of stem cells specifically engineered to replace the types that have been lost.

2. Accumulation of cells that are not wanted. These are (a) fat cells, which tend to proliferate and not only replace muscle but also lead to diabetes by diminishing the body's ability to respond to the pancreatic hormone insulin, and (b) cells that have become senescent, which accumulate in the cartilage of our joints. Receptors on the surface of such cells are susceptible to immune bodies that de Grey believes scientists will in time learn how to generate, or to other compounds that may make the cells destroy themselves without affecting others that do not have those distinctive receptors.

3. Mutations in chromosomes. The most damaging consequence of cell mutation is the development of cancer. The immortality of cancer cells is related to the behavior of the telomere, the caplike structure found on the end of every chromosome, which decreases in length each time the cell divides and therefore seems to be involved with the cell's mortality. If we could eliminate the gene that makes telomerase—the enzyme that maintains and lengthens telomeres—the cancer cell would die. De Grey's solution for this problem is to replace a person's stem cells every 10 or so years with ones engineered not to carry that gene.

4. Mutations in mitochondria. Mitochondria are the micromachines that produce energy for the cell's activities. They contain small amounts of DNA, which are particularly susceptible to mutations since they are not housed in the chromosomes of the nucleus. De Grey proposes copying the genes (of which there are 13) from the mitochondrial DNA and then putting those copies into the DNA of the nucleus, where they will be far safer from mutation-causing influences.

These are enormously complex biological problems that researchers have not come close to solving.

5. The accumulation of "junk" within the cell. The junk in question is a collection of complex material that results from the cell's breakdown of large molecules. Intracellular structures called lysosomes are the primary microchambers for such breakdown; the junk tends to collect in them, causing problems in the function of certain types of cells. Atherosclerosis, hardening of the arteries, is the biggest manifestation of these complications. To solve this difficulty, de Grey proposes to provide the lysosomes with genes to produce the extra enzymes required to digest the unwelcome material. The source of these genes will be certain soil bacteria, an innovation based on the observation that ground that contains buried animal flesh does not show accumulation of degraded junk.

6. The accumulation of "junk" outside the cell. The fluid in which all cells are bathed—called extracellular fluid—may come to contain aggregates of protein material that it is incapable of breaking down. The result is the formation of a substance called amyloid, which is the material found in the brains of people with Alzheimer's disease. To counter this, de Grey proposes vaccination with an as-yet undeveloped substance that might stimulate the immune system to produce cells to engulf and eat the offending material.

7. Cross-links in proteins outside the cell. The extracellular fluid contains many flexible protein molecules that exist unchanged for long periods of time, whose function is to give certain tissues such qualities as elasticity, transparence, or high tensile strength. Over a lifetime, occasional chemical reactions gradually affect these molecules in ways that change their physical and/or chemical qualities. Among these changes is the development of chemical bonds called cross-links between molecules that had previously moved independently of one another. The result is a loss of elasticity or a thickening of the involved tissue. If the tissue is the wall of an artery, for example, the loss of distensibility may lead to high blood pressure. De Grey's solution to this problem is to attempt to identify chemicals or enzymes capable of breaking cross-links without injuring anything else.

It must be obvious that, even condensed and simplified as they are here, these seven factors are enormously complex biological problems with even more complex proposed solutions. At least some of those solutions may prove inadequate, and others may be impossible to implement. Moreover, de Grey's descriptions are sprinkled with such vague phrases as "growth factors" and "stimulate the immune system," which might prove to be little more than slogans, as when he invokes yet-to-be-discovered "chemicals or enzymes capable of breaking cross-links without injuring anything else." In addition, it must be emphasized that researchers have not come close to solving a single one of the seven problems. In the case of several, there have been promising results. Indeed, research on extracellular cross-links has already yielded several drug candidates: a company called Alteon, in Parsippany, NY, has begun clinical trials of molecules that it says can reverse the effects of some conditions associated with age. In the cases of

some of the other problems de Grey identifies, however—such as the prevention of telomere lengthening or the transfer of mitochondrial DNA to the nucleus—it is fair to say that molecular biologists can only speculate about the day, if ever, when these attempts will come to fruition.

But de Grey is unfazed by this incompleteness. It is his thesis that time is being lost, and nothing is accomplished by pessimism about possibilities. For de Grey, "pie in the sky," as one biogerontologist I consulted called his formulations, is a tasty delicacy whose promise already nourishes his soul.

But others can challenge de Grey's science. My purpose was something else entirely. I found myself wondering what sort of man would devote the labors of an incandescently brilliant mind and a seemingly indefatigable constitution to such a project. Not only does the science seem more than a little speculative, but even more speculative is the assumption on which the entire undertaking is based—namely, that it is a good thing for the men and women now populating the earth to have the means to live indefinitely.

I arrived at the Eagle a few minutes early on the appointed day, which gave me time to record some of the words on the memorial plaque near the entryway, which read "An inn has existed at this site since 1667, called 'Eagle and Child.'... During their research in the early 1950s, Watson and Crick used the Eagle as a place to relax and discuss their theories whilst refreshing themselves with ale."

Thus properly steeped in history and atmosphere, I entered the pub just in time to see de Grey through the window, parking his ancient bicycle across the narrow street. Narrow, in fact, precisely describes the man himself, who stands six feet tall, weighs 147 pounds. His spareness is accentuated by a mountain-man chestnut beard extending down to mid-thorax that seems never to have seen a comb or brush. He was dressed like an unkempt graduate student, uncaring of tailoring considerations of any sort, wearing a hip-length black mackinaw-type coat that was borderline shabby. Adorning his head was a knitted woolen hat of a half-dozen striped transverse colors, which he told me had been crafted by his wife 14 years ago. As if to prove its age, the frazzled headgear (which was knitted with straplike extensions that tied under the chin) was not without a few holes. When he removed it, I saw that de Grey's long straight hair was held in a ponytail by a circular band of bright red wool. But in spite of the visual gestalt, de Grey cannot disguise the fact that he is a boyishly handsome man. As for his voice, being the product of a private school followed by Harrow and then Cambridge, it hardly needs to be described. To an American, he is of rare fauna, and his distinctiveness was catch-your-eye apparent even among his Cambridge colleagues.

Having seen a photo of de Grey on his website, I was prepared for his beard, spareness, and even his laissez-faire attitude toward externals. But I was not prepared for the intensity of those keen blue-gray eyes, nor for the pallor of the face in which they are so gleamingly set. His expression was one of concentrated zeal, even evangelism, and it never let up during our subsequent six hours of nonstop conversation across the narrow pub table that separated us. In the photo, his eyes are so gently warm that I had commented on them in one of my e-mails.

I was not prepared for the intensity of those keen blue-gray eyes, nor for the pallor of the face in which they are set.

But I would see none of that warmth during the 10 hours we spent together, though it reappeared in the 15 minutes during which we chatted with Adelaide de Grey in a courtyard between laboratory buildings after our Monday session at the Eagle.

Adelaide de Grey (née Carpenter) is a highly accomplished American geneticist and an expert electron microscopist who, at 60, is 19 years older than her husband. They met early in 1990, midway through her Cambridge sabbatical from a faculty position at the University of California, San Diego, and were married in April 1991. Neither of them has ever wanted to have children. "There are already lots of people who are very good at that," explained Aubrey when the subject came up. "It's either that or do a lot of stuff you wouldn't do if you had children, because you wouldn't have the time." Raised as the only child of an artistic and somewhat eccentric single mother, already at the age of eight or nine he had determined to do something with his life "that would make a difference," something that he and perhaps no one else was equipped to accomplish. Why fritter away resources in directions that others might pursue just as well or better? With that in mind no less now than when he was a child, de Grey has trimmed from his days and thoughts any activity he deems superfluous or distracting from the goals he sets for himself. He and Adelaide are two highly focused—some would say driven—people of such apparent similarity of motivation and goals that their work is the overwhelming catalytic force of their lives.

And yet, each member of this uncommon pair is touchingly tender with the other. Even my brief 15 minutes with them was sufficient to observe the softness that comes into de Grey's otherwise determined visage when Adelaide is near, and her similar response. I suspect that his website photo was taken while he was either looking at or thinking of her.

Adelaide, although at five foot two much shorter than her husband, looks his perfect sartorial partner: she dresses in a similar way and is apparently just as uncaring about her appearance or grooming. One can easily imagine them on one of their dates, as described by Aubrey. Walking from the small flat where they have lived since they married almost 14 years ago, entering the local laundromat, talking science as the machines beat up on their well-worn clothes. They are hardly bons vivants, nor would they want to be; they quite obviously like things just the way they are. They appear to care not at all for the usual getting and spending, nor even for some of the normative emotional rewards of living in our world—all at a time when the name of Aubrey de Grey has become associated with changing that world in unimaginable ways.

But six uninterrupted hours of compelling talk (most of it pouring out of him in floods of volubility let loose by intermittent questions or comments) and the consumption of numerous pints of Abbot's ale still awaited us before I would meet Adelaide and be taken to the laboratory where de Grey performs the duties of his "day job." Very soon after we began speaking, an hour before noon on that first day, I asked him why his proposals raise the hackles of so many gerontologists. And right there, at the very outset of our discussions, he replied with the dismissive impatience that would reappear whenever I brought up one or another of the many objections that either a specialist or layperson might have regarding the no-

tion of extending life for millennia. "Pretty much invariably," he curtly told me, their objections "are based on simple ignorance." Among the bands of that spectrum that de Grey will not confine to a bushel is his feeling that his is one of the few minds capable of comprehending the biology of his formulations, the scientific and societal logic upon which they are based, and the vastness of their potential benefits to our species.

I wanted de Grey to justify his conviction that living for thousands of years is a good thing. Certainly, if one can accept such a viewpoint, everything else follows from it: the push to research beyond the elucidation of the aging process; the gigantic investment of talent and money to accomplish and apply such research; the transformation of a culture based on the expectation of a finite and relatively short lifetime to one without horizons; the odd fact that every adult human being would be physiologically the same age (because rejuvenation would be the inevitable result of de Grey's proposals); the effects on family relationships—it goes on and on.

De Grey's response to such a challenge comes in the perfectly formed and articulated sentences that he uses in all his writings. He has the gift of expressing himself both verbally and in print with such clarity and completeness that a listener finds himself entranced by the flow of *seemingly* logical statements following one after the other. In speech as in his directed life, de Grey never rambles. Everything he says is pertinent to his argument, and so well constructed that one becomes fascinated with the edifice being formed before one's eyes. So true is this that I could not but fix my full attention on him as he spoke. Though many possible distractions arose during the hours in which we confronted each other across that pub table, as people came and went, ate and drank, talked and laughed, and smoked and coughed, I never once found myself looking anywhere but directly at him, except when going to fetch food—a full lunch for me and only potato chips for him—or another pint. It was only when reflecting upon the assumptions on which his argument is based that a listener discovers that he must insert the word "seemingly" before "logical" in the second sentence of the present paragraph. Here follows an aliquot of de Grey's reasoning:

> *The reason we have an imperative, we have a duty, to develop these therapies as soon as possible is to give future generations the choice. People are entitled, have a human right, to live as long as they can; people have a duty to give people the opportunity to live as long as they want to. I think it's just a straightforward extension of the duty-of-care concept. People are entitled to expect to be treated as they would treat themselves.*
>
> *It follows directly and irrevocably as an extension of the golden rule. If we hesitate and vacillate in developing life-extension therapy, there will be some cohort to whom we will deny the option to live much longer than we do. We have a duty not to deny people that option.*

When I raised the question of ethical or moral objections to the extreme extension of life, the reply was similarly seemingly logical and to the point:

> *If there were such objections, they would certainly count in this argument. What does count is that the right to live as long as you choose is the world's most fundamental right. And this is not something I'm ordaining. This seems to be something that all moral codes, religious or secular, seem to agree on: that the right to life is the most important right.*

And then, to what would seem the obvious objection that such moral codes assume our current life span and not one lasting thousands of years:

> *It's an incremental thing. It's not a question of how long life should be, but whether the end of life should be hastened by action or inaction.*

And there it is—the ultimate leap of ingenious argumentation that would do a sophist proud: by our inaction in not pursuing the possible opportunity of extending life for thousands of years, we are hastening death.

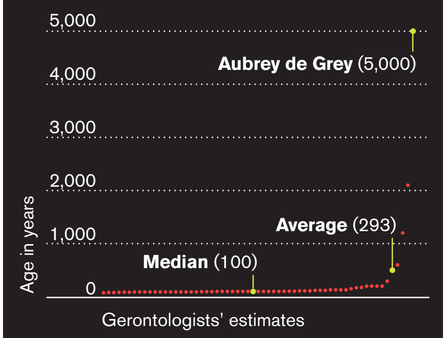
No word of the foregoing quotes has been edited or changed in any way. De Grey speaks in formed paragraphs and pages. Many readers of *Technology Review* are all too familiar with how garbled we often sound when quoted directly. Not so de Grey, who speaks with the same precision with which he writes. Admittedly, some may consider his responses to have the sound of a carefully prepared sermon or sales pitch because he has answered similar questions many times before, but all thought of such considerations disappears when one spends a bit of time with him and realizes that he pours forth every statement in much the same way, whether responding to some problem he has faced a dozen times before or giving a tour of the genetics lab where he works. His every thought comes out perfectly shaped, to the amazement of the bemused observer.

De Grey does not fool himself about the vastness of the efforts that will be required to make the advances in science and technology necessary to attain his objective. But equally, he does not seem fazed by my suggestion that his optimism might simply be based on the fact that, having never worked as a bench researcher in biology, he may not appreciate or even understand the nature of complex biological systems, nor fully take into account the possible consequences of tinkering with what he sees as individual components in a machine. Unlike engineers, the adoption of whose methodology de Grey considers his main conceptual contribution to solving the problems of aging, biologists do not approach physiological events as distinct entities that have no effect on any others. Each of de Grey's interventions will very likely result in unpredictable and incalculable responses in the biochemistry and

Living after 2100

Most gerontologists surveyed believe that an infant born in 2100 in a developed country will live to be between 80 and 100 years old, slightly older than today's average of about 75. But some argued that the average age will be much higher.

Estimates by 60 gerontologists of the average life expectancy of a person born in 2100



SOURCE: THE JOURNAL OF ANTI-AGING MEDICINE

physics of the cells he is treating, not to mention their extracellular milieu and the tissues and organs of which they are a part. In biology, everything is interdependent; everything is affected by everything else. Though we study phenomena in isolation to avoid complicating factors, those factors come into play with a vengeance when in vitro becomes in vivo. The fearsome concerns are many: a little lengthening of the telomere here, a bit of genetic material from a soil bacterium there, a fistful of stem cells—the next thing you know, it all explodes in your face.

He replied to all this as to so much else, whether it be the threat of overpopulation, the effect on relationships within families and whole societies, or the need to find employment for vibrantly healthy people who are a thousand years old: we will deal with these problems as they come up. We will make the necessary adjustments, whether in the realm of potential cellular havoc or of the tortuosities of economic necessity. He believes that each problem can be retouched and remedied as it becomes recognized.

De Grey has some interesting notions of human nature. He insists that, on the one hand, it is basic to humankind to want to live forever regardless of consequences, while on the other it is not basic to want to have children. When I protested that the two most formative instincts of all living things are to survive and to pass on their DNA, he quickly made good use of the one and denied the existence of the other. Bolstering his argument with the observation that many people—like Adelaide and himself—choose not to have children, he replied, not without a hint of petulance and some small bit of excited waving of his hands,

> *Your precept is that we all have the fundamental impulse to reproduce. The incidence of voluntary childlessness is exploding. Therefore the imperative to reproduce is not actually so deep seated as psychologists would have us believe. It may simply be that it was the thing to do—the more traditional thing. My point of view is that a large part of it may simply be indoctrination....I'm not in favor of giving young girls dolls to play with, because it may perpetuate the urge to motherhood.*

De Grey has commented in several fora on his conviction that, given the choice, the great majority of people would choose life extension over having children and the usual norms of family life. This being so, he says, far fewer children would be born. He did not hesitate to say the same to me:

> *We will realize there is an overpopulation problem, and if we have the sense we'll decide to fix it [by not reproducing] sooner rather than later, because the sooner we fix it the more choice we'll have about how we live and where we live and how much space we will have and all that. Therefore, the question is, what will we do? Will we decide to live a long time and have fewer children, or will we decide to reject these rejuvenation therapies in order that we can have children? It seems pretty damn clear to me that we'll take the former option, but the point is that I don't know and I don't need to know.*

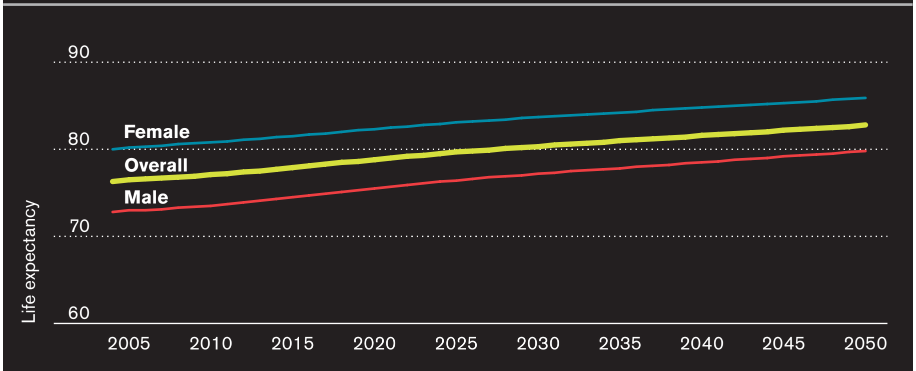
Of course, de Grey's reason for not needing to know is that same familiar imperative he keeps returning to, the imperative that everyone is entitled to choice regardless of the possible consequences. What we need to know, he argues, can be found out after the fact and dealt with when it appears. Without giving humankind the choice, however, we deprive it of its most basic liberty. It should not be surprising that a man as insistently individualistic—and as uncommon a sort—as he would emphasize freedom of personal choice far more than the potentially toxic harvest that might result from cultivating that dangerous seed in isolation. As with every other of his formulations, this one—the concept of untrammeled freedom of choice for the individual—is taken out of the context of its biological and societal surroundings. Like everything else, it is treated in vitro rather than in vivo.

In campaigns that occur across the length of several continents, de Grey's purpose is only secondarily to overcome resistance to his theories. His primary aim is to publicize himself and his formulations as widely as possible, not for the sake of personal glory but as a potential means of raising the considerable funding that will be necessary to carry out the research that needs to be done if his plans are to stand any chance of so much as partial success. He has laid out a schedule projecting the timeline on which he would like to see certain milestones reached.

The first of these milestones would be to rejuvenate mice. De Grey would extend the life span of a two-year-old mouse that might ordinarily live one more year by three years. He believes funding of around $100 million a year will make this feasible "10 years from now; almost certainly not as soon as seven years; but very likely... less than 20 years." Such an accomplishment, de Grey believes, will "kick-start a war on aging" and be "the trigger for enormous social upheaval." In an article for the *Annals of the New York Academy of Sciences* [de Grey et al., 959: 452–462, 2002], which lists seven coauthors after his own name, de Grey writes, "We contend that the impact on public opinion

The Sensible Census

The U.S. Bureau of the Census estimates that, over the next 45 years, life expectancy at birth in developed countries will increase by an average of about six years.



SOURCE: THE U.S. BUREAU OF THE CENSUS

and (inevitably) public policy of unambiguous aging-reversal in mice would be so great that whatever work remained necessary at that time to achieve adequate somatic gene therapy would be hugely accelerated." Not only that, he asserts, but the public enthusiasm following upon such a feat will cause many people to begin making life choices based on the probability that they, too, will reach a proportional number of years. Moreover, when death from a disease like influenza, for example, is considered premature at the age of 200, the urgent need to solve the problems of infectious disease will massively increase government and drug company funding in that area.

In addition to accelerating demand for research, the tripling of a middle-aged mouse's remaining life span would bring in entirely new sources of funding. Because governments and drug companies tend to favor research that promises useful results in a relatively short time, de Grey is not counting on them as a source. He is relying on an infusion of private money to supply the funds (significantly more than the cost of reversing aging in mice) that it will take to successfully fight his war against aging in humans. De Grey believes that once aging has been reversed in mice, billionaires will come forward, intent on living as long as possible.

Is it likely that the photograph of a long-lived mouse on the front page of every newspaper in the world would be greeted with the unalloyed enthusiasm of a unanimous public? I doubt it. More probably, acclaim would be balanced by horror. Ethicists, economists, sociologists, members of the clergy, and many worried scientists could be counted on to join huge numbers of thoughtful citizens in a counterreaction. But of course, if we are to accept de Grey's first principle, that the desire to live forever trumps every other factor in human decision-making, then self-interest—or what some might call narcissism—will win out in the end.

De Grey projects that 15 years after we have rejuvenated mice we might begin to reverse aging in humans. Early, limited success in extending the human life span will be followed by successive, more dramatic breakthroughs, so that humans now living could reach what de Grey calls "life extension escape velocity." De Grey concedes that it might be 100 years before we begin to significantly extend human life. What he does not concede is that it is more likely not to happen at all. He cannot seem to imagine that the odds are heavily against him. And he cannot imagine that not only the odds but society itself may be against him. He will provide any listener or reader with a string of reasons that are really rationalizations to explain why most mainstream gerontologists remain so conspicuously absent from the ranks of those cheering him on. He has safeguarded himself against the informed criticism that should give him cause to rethink some of his proposals. He has accomplished this self-protection by constructing a personal worldview in which he is inviolate. He refuses to budge a millimeter; he will not give ground to the possibility that any of the barriers to his success may prove insuperable.

All this makes de Grey sound unlikable. But a major factor behind his success at attracting a following has less to do with his science than with himself. As I discovered during our two sessions at the Eagle, it is impossible not to like de Grey. Despite his unhesitant verbal trashing of those who disagree with him, there is a certain untouched sweetness in the man, which, combined with his lack of care for outward appearance and the sincerity of his commitment to the goals that animate his life, are so disarming that the entire picture is one of the disingenuousness of genius, rather than of the self-promotion of the remote, false messiah. His likability was pointed out even by his detractors. It is a quality not to be expected in such an obviously odd and driven duck.

It will not be a neutral or malevolent force that will do us in, but one whose only motivation is to improve us.

But the most likable of eccentrics are sometimes the most dangerous. Many decades ago in my naïveté and ignorance, I thought that the ultimate destruction of our planet would be by the neutral power of celestial catastrophe: collision with a gigantic meteor, the burning out of the sun—that sort of thing. In time, I came to believe that the end of days would be ushered in by the malevolence of a mad dictator who would unleash an arsenal of explosive or biological weaponry: nuclear bombs, engineered microörganisms—that sort of thing. But my notion of "that sort of thing" has been changing. If we are to be destroyed, I am now convinced that it will not be a neutral or malevolent force that will do us in, but one that is benevolent in the extreme, one whose only motivation is to improve us and better our civilization. If we are ever immolated, it will be by the efforts of well-meaning scientists who are convinced that they have our best interests at heart. We already know who they are. They are the DNA tweakers who would enhance us by allowing parents to choose the genetic makeup of their descendants unto every succeeding generation ad infinitum, heedless of the possibility that breeding out variety may alter factors necessary for the survival of our species and the health of its relationship to every form of life on earth; they are the biogerontologists who study caloric restriction in mice and promise us the extension by 20 percent of a peculiarly nourished existence; they are those other biogerontologists who emerge from their laboratories of molecular science every evening optimistic that they have come just a bit closer to their goal of having us live much longer, downplaying the unanticipated havoc at both the cellular and societal level that might be wrought by their proposed manipulations. And finally, it is the unique and strangely alluring figure of Aubrey de Grey, who, orating, writing, and striding tirelessly through our midst with his less than fully convinced sympathizers, proclaims like the disheveled herald of a new-begotten future that our most inalienable right is to have the choice of living as long as we wish. With the passion of a single-minded zealot crusading against time, he has issued the ultimate challenge, I believe, to our entire concept of the meaning of humanness. Paradoxically, his clarion call to action is the message neither of a madman nor a bad man, but of a brilliant, beneficent man of goodwill, who wants only for civilization to fulfill the highest hopes he has for its future. It is a good thing that his grand design will almost certainly not succeed. Were it otherwise, he would surely destroy us in attempting to preserve us. ■

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Fraud, gruesome propaganda, terror planning: the Net enables it all. The online industry can help fix it.

TERROR'S SERVER

By David Talbot

ILLUSTRATION BY TAVIS COBURN

TWO HUNDRED TWO PEOPLE DIED IN THE BALI, Indonesia, disco bombing of October 12, 2002, when a suicide bomber blew himself up on a tourist-bar dance floor, and then, moments later, a second bomber detonated an explosives-filled Mitsubishi van parked outside. Now, the mastermind of the attacks—Imam Samudra, a 35-year-old Islamist militant with links to al-Qaeda—has written a jailhouse memoir that offers a primer on the more sophisticated crime of online credit card fraud, which it promotes as a way for Muslim radicals to fund their activities.

Law enforcement authorities say evidence collected from Samudra's laptop computer shows he tried to finance the Bali bombing by committing acts of fraud over the Internet. And his new writings suggest that online fraud—which in 2003 cost credit card companies and banks \$1.2 billion in the United States alone—might become a key weapon in terrorist arsenals, if it's not already. "We know that terrorist groups throughout the world have financed themselves through crime," says Richard Clarke, the former U.S. counterterrorism czar for President Bush and President Clinton. "There is beginning to be a reason to conclude that one of the ways they are financing themselves is through cyber-crime."

Online fraud would thereby join the other major ways in which terrorist groups exploit the Internet. The September 11 plotters are known to have used the Internet for international communications and information gathering. Hundreds of jihadist websites are used for propaganda and fund-raising purposes and are as easily accessible as the mainstream websites of major news organizations. And in 2004, the Web was awash with raw video of hostage beheadings perpetrated by followers of Abu Musab al-Zarqawi, the Jordanian-born terror leader operating in Iraq. This was no fringe phenomenon. Tens of millions of people downloaded the video files, a kind of vast medieval spectacle enabled by numberless Web hosting companies and Internet service providers, or ISPs. "I don't know where the line is. But certainly, we have passed it in the abuse of the Internet," says Gabriel Weimann, a professor of communications at the University of Haifa, who tracks use of the Internet by terrorist groups.

Meeting these myriad challenges will require new technology and, some say, stronger self-regulation by the online industry, if only to ward off the more onerous changes or restrictions that might someday be mandated by legal authorities or by the security demands of busi-

ness interests. According to Vinton Cerf, a founding father of the Internet who codesigned its protocols, extreme violent content on the Net is "a terribly difficult conundrum to try and resolve in a way that is constructive." But, he adds, "it does not mean we shouldn't do anything. The industry has a fair amount of potential input, if it is to try to figure out how on earth to discipline itself. The question is, which parts of the industry can do it?" The roadblocks are myriad, he notes: information can literally come from anywhere, and even if major industry players agree to restrictions, Internet users themselves could obviously go on sharing content. "As always, the difficult question will be, Who decides what is acceptable content and on what basis?"

Some work is already going on in the broader battle against terrorist use of the Internet. Research labs are developing new algorithms aimed at making it easier for investigators to comb through e-mails and chat-room dialogue to uncover criminal plots. Meanwhile, the industry's antispam efforts are providing new tools for authenticating e-mail senders using cryptography and other methods, which will also help to thwart fraud; clearly, terrorist exploitation of the Internet adds a national-security dimension to these efforts. The question going forward is whether the terrorist use of the medium, and the emerging responses, will help usher in an era in which the distribution of online content is more tightly controlled and tracked, for better or worse.

The Rise of Internet Terror

Today, most experts agree that the Internet is not just a tool of terrorist organizations, but is central to their operations*. Some say that al-Qaeda's online presence has become more potent and pertinent than its actual physical presence since the September 11 attacks. "When we say al-Qaeda is a global ideology, this is where it exists—on the Internet," says Michael Doran, a Near East scholar and terrorism expert at Princeton University. "That, in itself, I find absolutely amazing. Just a few years ago, an organization like this would have been more cultlike in nature. It wouldn't be able to spread around the world the way it does with the Internet."

The universe of terror-related websites extends far beyond al-Qaeda, of course. According to Weimann, the number of such websites has leapt from only 12 in 1997 to around 4,300 today. (This includes sites operated by groups like Hamas and Hezbollah, and others in South America and other parts of the world.) "In seven years it has exploded, and I am quite sure the number will grow next week and the week after," says Weimann, who described the trend in his report "How Modern Terrorism Uses the Internet," published by the United States Institute of Peace, and who is now at work on a book, *Terrorism and the Internet*, due out later this year.

These sites serve as a means to recruit members, solicit funds, and promote and spread ideology. "While the [common] perception is that [terrorists] are not well educated or very sophisticated about telecommunications or the Internet, we know that that isn't true," says Ronald Dick, a former FBI deputy assistant director who headed the FBI's National Infrastructure Protection Center. "The individuals that the FBI and other law enforcement agencies have arrested have engineering and telecommunications backgrounds; they have been trained in academic institutes as to what these capabilities are." (Militant Islam, despite its roots in puritanical Wahhabism, taps the well of Western liberal education: Khalid Sheikh Mohammed, the principal September 11 mastermind, was educated in the U.S. in mechanical engineering; Osama bin Laden's deputy Ayman al-Zawahiri was trained in Egypt as a surgeon.)

The Web gives jihad a public face. But on a less visible level, the Internet provides the means for extremist groups to surreptitiously organize attacks and gather information. The September 11 hijackers used conventional tools like chat rooms and e-mail to communicate and used the Web to gather basic information on targets, says Philip Zelikow, a historian at the University of Virginia and the former executive director of the 9/11 Commission. "The conspirators used the Internet, usually with coded messages, as an important medium for international communication," he says. (Some aspects of the terrorists' Internet use remain classified; for example, when asked whether the Internet played a role in recruitment of the hijackers, Zelikow said he could not comment.)

Finally, terrorists are learning that they can distribute images of atrocities with the help of the Web. In 2002, the Web facilitated wide dissemination of videos showing the beheading of *Wall Street Journal* reporter Daniel Pearl, despite FBI requests that websites not post them. Then, in 2004, Zarqawi made the gruesome tactic a cornerstone of his terror strategy, starting with the murder of the American civilian contractor Nicholas Berg—which law enforcement agents believe was carried out by Zarqawi himself. From Zarqawi's perspective, the campaign was a rousing success. Images of orange-clad hostages became a headline-news staple around the world—and the full, raw videos of their murders spread rapidly around the Web. "The Internet allows a small group to publicize such horrific and gruesome acts in seconds, for very little or no cost, worldwide, to huge audiences, in the most powerful way," says Weimann.

And there's a large market for such material. According to Dan Klinker, webmaster of a leading online gore site, Ogrish.com, consumption of such material is brisk. Klinker, who says he operates from offices in Western and Eastern Europe and New York City, says his aim is to "open people's eyes and make them aware of reality." It's clear that many eyes have taken in these images thanks to sites like his. Each beheading video has been downloaded from Klinker's site several million times, he says, and the Berg video tops the list at 15 million. "During certain events (beheadings, etc.) the servers can barely handle the insane bandwidths—sometimes 50,000 to 60,000 visitors an hour," Klinker says.

Avoiding the Slippery Slope

To be sure, Internet users who want to block objectionable content can purchase a variety of filtering-software products that attempt to block sexual or violent content. But they are far from perfect. And though a hodgepodge of Web page rating schemes are in various stages of implementation, no universal rating system is in effect—and none is mandated—that would make filters chosen by consumers more effective.

* WWW.TECHNOLOGYREVIEW.COM For more on the dimensions of terrorist use of the Internet, see our extended Q&A with Richard Clarke. Keyword Clarke.

But passing laws aimed at allowing tighter filtering—to say nothing of actually mandating filtering—is problematical. Laws aimed at blocking minors' access to pornography, like the Communications Decency Act and Children's Online Protection Act, have been struck down in the courts on First Amendment grounds, and the same fate has befallen some state laws, often for good reason: the filtering tools sometimes throw out the good with the bad. "For better or worse, the courts are more concerned about protecting the First Amendment rights of adults than protecting children from harmful material," says Ian Ballon, an expert on cyberspace law and a partner at Manatt, Phelps, and Phillips in Palo Alto, CA. Pornography access, he says, "is something the courts have been more comfortable regulating in the physical world than on the Internet." The same challenges pertain to images of extreme violence, he adds.

The Federal Communications Commission enforces "decency" on the nation's airwaves as part of its decades-old mission of licensing and regulating television and radio stations. Internet content, by contrast, is essentially unregulated. And so, in 2004, as millions of people watched video of beheadings on their computers, the FCC fined CBS $550,000 for broadcasting the exposure of singer Janet Jackson's breast during the Super Bowl halftime show on television.

"While not flatly impossible, [Internet content] regulation is hampered by the variety of places around the world at which it can be hosted," says Jonathan Zittrain, codirector of the Berkman Center for Internet and Society at Harvard Law School—and that's to say nothing of First Amendment concerns. As Zittrain sees it, "it's a gift that the sites are up there, because it gives us an opportunity for counterintelligence."

As a deterrent, criminal prosecution has also had limited success. Even when those suspected of providing Internet-based assistance to terror cells are in the United States, obtaining convictions can be difficult. Early last year, under provisions of the Patriot Act, the U.S. Department of Justice charged Sami Omar al-Hussayen, a student at the University of Idaho, with using the Internet to aid terrorists. The government alleged that al-Hussayen maintained websites that promoted jihadist-related activities, including funding terrorists. But his defense argued that he was simply using his skills to promote Islam and wasn't responsible for the sites' radical content. The judge reminded the jury that, in any case, the Constitution protects most speech. The jury cleared al-Hussayen on the terrorism charges but deadlocked on visa-related charges; al-Hussayen agreed to return home to his native Saudi Arabia rather than face a retrial on the visa counts.

Richard Clarke

CHRISTOPHER HARTLOVE

Industry adoption of tighter editorial controls would be a matter of good taste and of supporting the war on terror, says Richard Clarke.

Technology and ISPs

But the government and private-sector strategy for combatting terrorist use of the Internet has several facets. Certainly, agencies like the FBI and the National Security Agency—and a variety of watchdog groups, such as the Site Institute, a nonprofit organization based in an East Coast location that it asked not be publicized—closely monitor jihadist and other terrorist sites to keep abreast of their public statements and internal communications, to the extent possible.

It's a massive, needle-in-a-haystack job, but it can yield a steady stream of intelligence tidbits and warnings. For example, the Site Institute recently discovered, on a forum called the Jihadi Message Board, an Arabic translation of a U.S. Air Force Web page that mentioned an American airman of Lebanese descent. According to Rita Katz, executive director of the Site Institute, the jihadist page added, in Arabic, "This hypocrite will be going to Iraq in September of this year [2004]—I pray to Allah that his cunning leads to his slaughter. I hope that he will be slaughtered the Zarqawi's way, and then [go from there] to the lowest point in Hell." The Site Institute alerted the military. Today, on one if its office walls hangs a plaque offering the thanks of the Air Force Office of Special Investigations.

New technology may also give intelligence agencies the tools to sift through on-

line communications and discover terrorist plots. For example, research suggests that people with nefarious intent tend to exhibit distinct patterns in their use of e-mails or online forums like chat rooms. Whereas most people establish a wide variety of contacts over time, those engaged in plotting a crime tend to keep in touch only with a very tight circle of people, says William Wallace, an operations researcher at Rensselaer Polytechnic Institute.

This phenomenon is quite predictable. “Very few groups of people communicate repeatedly only among themselves,” says Wallace. “It’s very rare; they don’t trust people outside the group to communicate. When 80 percent of communications is within a regular group, this is where we think we will find the groups who are planning activities that are malicious.” Of course, not all such groups will prove to be malicious; the odd high-school reunion will crop up. But Wallace’s group is developing an algorithm that will narrow down the field of so-called social networks to those that warrant the scrutiny of intelligence officials. The algorithm is scheduled for completion and delivery to intelligence agencies this summer.

And of course, the wider fight against spam and online fraud continues apace. One of the greatest challenges facing antifraud forces is the ease with which con artists can doctor their e-mails so that they appear to come from known and trusted sources, such as colleagues or banks. In a scam known as “phishing,” this tactic can trick recipients into revealing bank account numbers and passwords. Preventing such scams, according to Clarke, “is relevant to counterterrorism because it would prevent a lot of cybercrime, which may be how [terrorists] are funding themselves. It may also make it difficult to assume identities for one-time-use communications.”

New e-mail authentication methods may offer a line of defense. Last fall, AOL endorsed a Microsoft-designed system called Sender ID that closes certain security loopholes and matches the IP (Internet Protocol) address of the server sending an inbound e-mail against a list of servers authorized to send mail from the message’s purported source. Yahoo, the world’s largest e-mail provider with some 40 million accounts, is now rolling out its own system, called Domain Keys, which tags each outgoing e-mail message with

Terrorism and the Internet

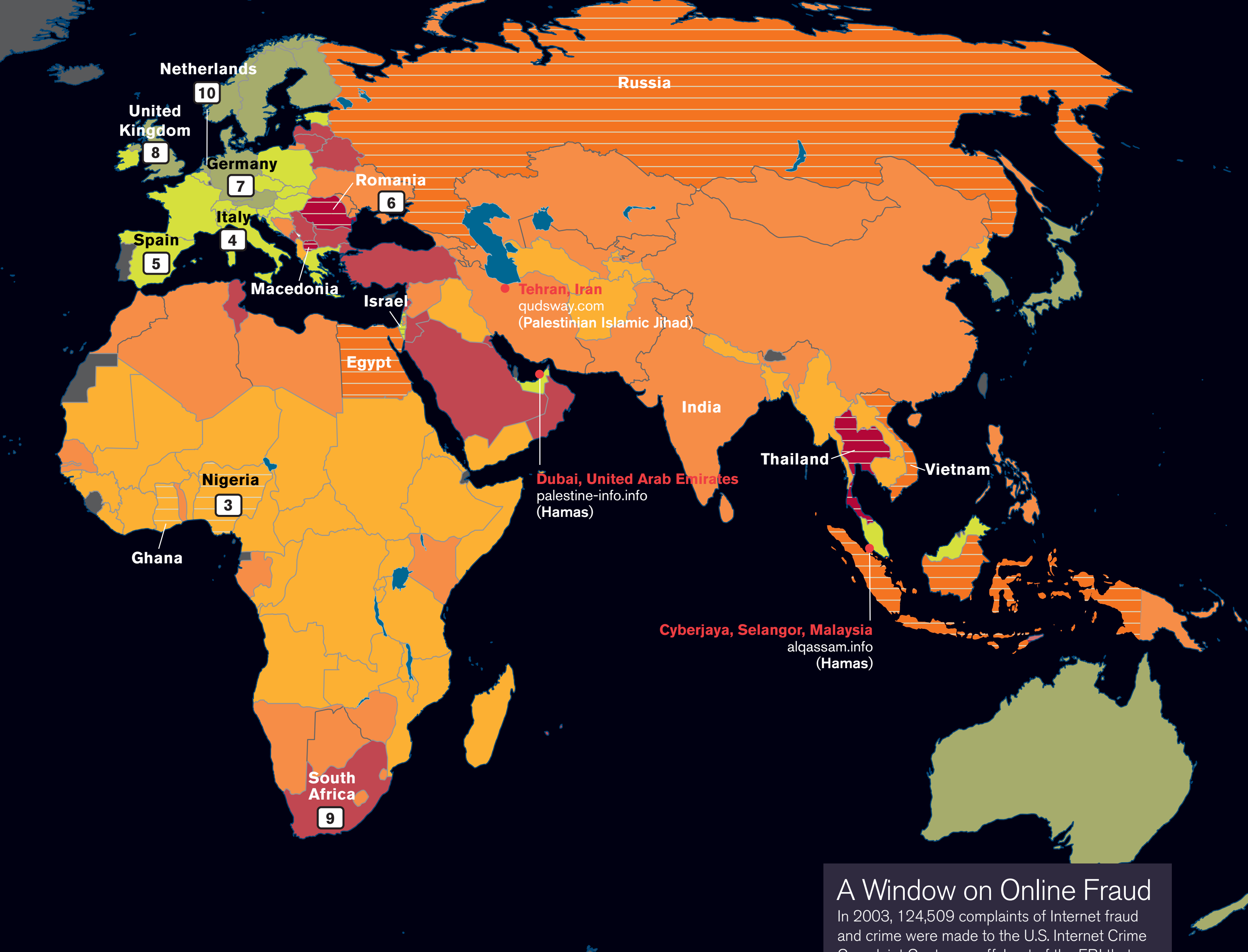
In the last decade, as Internet use has spread across the globe, online interaction has become integral to many social phenomena—including terrorism.

Terrorist organizations are taking advantage of the global reach of the Internet to recruit members, raise funds, and spread their ideologies. Gabriel Weimann, a professor at the University of Haifa in Israel, identifies 4,300 websites worldwide as terror related.

Displayed above is a sampling of terrorist websites and their server locations. This list was provided by the Site Institute, a U.S.-based watchdog group that monitors jihadist groups.

Online fraud, of course, is a distinct phenomenon. But law enforcement authorities are increasingly concerned that it could become a source of funds for terrorists. As the number of Internet users approaches one billion in the next few years, these trends may become even more pronounced. **STACY LAWRENCE**

SOURCE: NATIONAL WHITE COLLAR CRIME CENTER AND THE FEDERAL BUREAU OF INVESTIGATION (FRAUD DATA); MERCHANT RISK COUNCIL (PROBLEMATIC NATIONS); SITE INSTITUTE (TERRORIST WEBSITES); IDC (INTERNET USAGE).



KEY

Server location
Website URL
(Terrorist group)

Rank among nations with the most FBI-reported online fraud perpetrators

Countries identified in a survey of online merchants as problematic for Internet fraud

Internet users per 1,000 people

- 400–600
- 150–400
- 50–150
- 10–50
- <10
- NA

A Window on Online Fraud

In 2003, 124,509 complaints of Internet fraud and crime were made to the U.S. Internet Crime Complaint Center, an offshoot of the FBI that takes complaints largely from the United States. The perpetrators' reported home countries broke down as follows:

Rank	*Country*	*Reports*
1	United States	76.4%
2	Canada	3.3%
3	Nigeria	2.9%
4	Italy	2.5%
5	Spain	2.4%
6	Romania	1.5%
7	Germany	1.3%
8	United Kingdom	1.3%
9	South Africa	1.1%
10	Netherlands	0.9%

an encrypted signature that can be used by the recipient to verify that the message came from the purported domain. Google is using the technology with its Gmail accounts, and other big ISPs, including Earthlink, are following suit.

Finally, the bigger ISPs are stepping in with their own reactive efforts. Their "terms of service" are usually broad enough to allow them the latitude to pull down objectionable sites when asked to do so. "When you are talking about an online community, the power comes from the individual," says Mary Osako, Yahoo's director of communications. "We encourage our users to send [any concerns about questionable] content to us—and we take action on every report."

Too Little, or Too Much

But most legal, policy, and security experts agree that these efforts, taken together, still don't amount to a real solution. The new anti-spam initiatives represent only the latest phase of an ongoing battle. "The first step is, the industry has to realize there is a problem that is bigger than they want to admit," says Peter Neumann, a computer scientist at SRI International, a nonprofit research institute in Menlo Park, CA. "There's a huge culture change that's needed here to create trustworthy systems. At the moment we don't have anything I would call a trustworthy system." Even efforts to use cryptography to confirm the authenticity of e-mail senders, he says, are a mere palliative. "There are still lots of problems" with online security, says Neumann. "Look at it as a very large iceberg. This shaves off one-fourth of a percent, maybe 2 percent—but it's a little bit off the top."

But if it's true that existing responses are insufficient to address the problem, it may also be true that we're at risk of an overreaction. If concrete links between online fraud and terrorist attacks begin emerging, governments could decide that the Internet needs more oversight and create new regulatory structures. "The ISPs could solve most of the spam and phishing problems if made to do so by the FCC," notes Clarke. Even if the Bali bomber's writings don't create such a reaction, something else might. If no discovery of a a strong connection between online fraud and terrorism is made, another trigger could be an actual act of "cyberterrorism"—the long-feared use of the Internet to wage digital attacks against targets like city power grids and air traffic control or communications systems. It could be some online display of homicide so appalling that it spawns a new drive for online decency, one countenanced by a newly conservative Supreme Court. Terrorism aside, the trigger could be a pure business decision, one aimed at making the Internet more transparent and more secure.

Zittrain concurs with Neumann but also predicts an impending overreaction. Terrorism or no terrorism, he sees a convergence of security, legal, and business trends that will force the Internet to change, and not necessarily for the better. "Collectively speaking, there are going to be technological changes to how the Internet functions—driven either by the law or by collective action. If you look at what they are doing about spam, it has this shape to it," Zittrain says. And while technological change might improve online security, he says, "it will make the Internet less flexible. If it's no longer possible for two guys in a garage to write and distribute killer-app code without clearing it first with entrenched interests, we stand to lose the very processes that gave us the Web browser, instant messaging, Linux, and e-mail."

The first needed step: a culture change in the industry, to acknowledge a problem bigger than they want to admit, says Peter Neumann.

A concerted push toward tighter controls is not yet evident. But if extremely violent content or terrorist use of the Internet might someday spur such a push, a chance for preëmptive action may lie with ISPs and Web hosting companies. Their efforts need not be limited to fighting spam and fraud. With respect to the content they publish, Web hosting companies could act more like their older cousins, the television broadcasters and newspaper and magazine editors, and exercise a little editorial judgment, simply by enforcing existing terms of service.

Is Web content already subject to any such editorial judgment? Generally not, but sometimes, the hopeful eye can discern what appear to be its consequences. Consider the mysterious inconsistency among the results returned when you enter the word "beheading" into the major search engines. On Google and MSN, the top returns are a mixed bag of links to responsible news accounts, historical information, and ghoulish sites that offer raw video with teasers like "World of Death, Iraq beheading videos, death photos, suicides and crime scenes." Clearly, such results are the product of algorithms geared to finding the most popular, relevant, and well-linked sites.

But enter the same search term at Yahoo, and the top returns are profiles of the U.S. and British victims of beheading in Iraq. The first 10 results include links to biographies of Eugene Armstrong, Jack Hensley, Kenneth Bigley, Nicholas Berg, Paul Johnson, and Daniel Pearl, as well as to memorial websites. You have to load the second page of search results to find a link to Ogrish.com. Is this oddly tactful ordering the aberrant result of an algorithm as pitiless as the ones that churn up gore links elsewhere? Or is Yahoo, perhaps in a nod to the victims' memories and their families' feelings, making an exception of the words "behead" and "beheading," treating them differently than it does thematically comparable words like "killing" and "stabbing?"

Yahoo's Osako did not reply to questions about this search-return oddity; certainly, a technological explanation cannot be excluded. But it's clear that such questions are very sensitive for an industry that has, to date, enjoyed little intervention or regulation. In its response to complaints, says Richard Clarke, "the industry is very willing to coöperate and be good citizens in order to stave off regulation." Whether it goes further and adopts a stricter editorial posture, he adds, "is a decision for the ISP [and Web hosting company] to make as a matter of good taste and as a matter of supporting the U.S. in the global war on terror." If such decisions evolve into the industry-wide assumption of a more journalistic role, they could, in the end, be the surest route to a more responsible medium—one that is less easy to exploit and not so vulnerable to a clampdown. ■

David Talbot is Technology Review*'s chief correspondent.*

UNNATURAL SELECTION

Machines using genetic algorithms are better than humans at designing other machines

By Sam Williams ILLUSTRATION BY JOEL LARDNER

TO BECOME A PROFESSIONAL ANTENNA DESIGNER, you can follow one of two paths: you can enroll in college- and graduate-level courses on electromagnetism, immerse yourself in the empirical study of antenna shapes, and apprentice yourself to an established technician willing to impart the closely guarded secrets of the discipline.

Or you can do what Jason Lohn did: let evolution do the work.

Physicists know a lot about Maxwell's equations and the other principles governing wireless communications. But antenna design is still pretty much a dark art, says Lohn, a computer scientist working at NASA Ames Research Center outside Mountain View, CA. "The field is so squirrelly. All your learning is through trial and error, the school of hard knocks."

So why not automate trial and error? Antenna design, Lohn believes, is one of many engineering problems that could best be solved by evolutionary algorithms, an emerging class of software that produces lots of different designs, rejecting the less fit in order to select the most functional. The resulting designs often seem a little inhuman—inelegant and uncanny.

Evolutionary algorithms, also known as genetic algorithms or GAs, take their cue from biological evolution, which can turn a crawling reptile into a soaring bird without any kind of forward-looking blueprint. In sexual reproduction, the shuffling of each parent's genes—combined with random genetic mutation—creates organisms with new characteristics, and the less fit organisms tend not to pass on their genes to succeeding generations. Evolutionary algorithms work much the same way, but inside a computer.

When Lohn creates a new antenna, for example, he starts off with a population of randomly generated designs and grades their relative performance. Designs that come close to preset goals win the right to intermingle their properties with those of other successful candidates. Designs that disappoint go the way of the archaeopteryx: oblivion.

Breeding antennas takes time, of course. Most designs are downright awful, and it takes a large number of computing cycles to find decent performers. Still, when you've got a computer that can generate and test 1,000 generations an hour, interesting ideas do emerge*. Lohn, a PhD who hasn't taken a course on electromagnetism since his undergraduate years, expects to have at least one of his team's antenna designs go into space this year as part of NASA's Space Technology 5 mission, which will test a trio of miniature satellites. His favorite computer-designed antenna: a corkscrew contraption small enough to fit in a wine glass, yet able to send a wide-beam radio wave from space to Earth. It resembles nothing any sane radio engineer would build on her own.

"Evolutionary algorithms are a great tool for exploring the dark corners of design space," Lohn says. "You show [your designs] to people with 25 years' experience in the industry and they say, 'Wow, does that really work?'" The slightly spooky answer is that yes, they really do, as Lohn established after months of testing. "If we're lucky, we could have as many as six antenna designs going into space" in 2005, Lohn says.

Not every problem will succumb to the evolutionary approach. But those that will share a common characteristic: they all sit beyond what mathematician John von Neumann dubbed the "complexity barrier," the dividing line between problems that can be solved using traditional, reductionist methods and those that require a more intuitive, throw-it-up-and-see-what-sticks approach. Until recently, crossing this barrier was an expensive proposition. But today's computers are fast enough to sift through millions of offbeat designs in hope of finding one that works. Couple that with modern designers' growing skill in applying evolutionary algorithms, says David Goldberg, director of the Illinois Genetic Algorithms Laboratory at the University of Illinois at Urbana-Champaign, and you get what engineers lovingly call "scalability": the ability to tackle both miniature and massive design challenges.

NASA's corkscrew antenna resembles nothing any sane radio engineer would build on her own.

"Just as the steam engine created mechanical leverage to do larger tasks, genetic algorithms are starting to give individuals a kind of intellectual leverage that will reshape work," Goldberg says. "By automating some of the heavy lifting of thought, we free ourselves to operate at a higher, more creative level." Such freedom comes at a price, of course. It requires that engineers recognize the impossibility of peering into each and every "dark corner" and put their trust in yet another layer of mechanical assistance. But more and more of them are taking that leap.

* **WWW.TECHNOLOGYREVIEW.COM** We got our hands on a few clickable simulations that show how evolvable algorithms work. Keyword **evolution**.

From Toys to Tools

Reproducing in microseconds on a computer a process that takes millions of years in nature is an idea that long predates the ability to realize it. John H. Holland, a 76-year-old computer science professor at the University of Michigan, says he first came up with the notion while browsing through the Michigan math library's open stacks in the early 1950s.

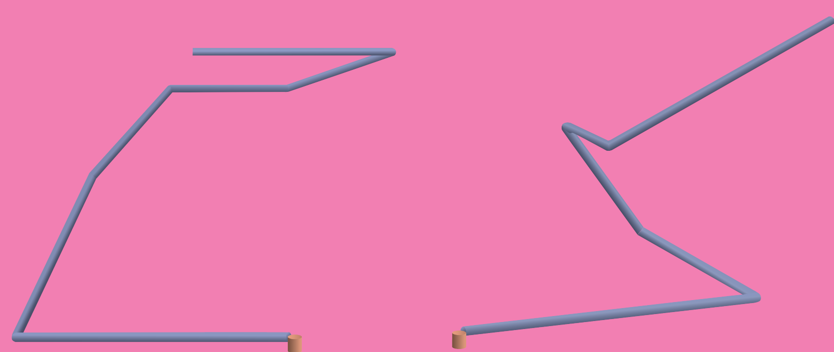
"Every once in a while I'd pick up a book that looked interesting and just read it," he says. That habit led him to *The Genetical Theory of Natural Selection*, a 1930 book by British mathematician-turned-biologist Ronald Fisher. Inspired by the pea plant experiments of 19th-century Austrian monk Gregor Mendel, Fisher worked out mathematical descriptions of natural selection at the level of individual genes. While researchers wouldn't crack the biochemistry behind that process until the 1950s, Fisher's work nevertheless jibed with what farmers and shepherds had known for centuries: sexual reproduction ensures variation and novelty.

"That's really where the genetic algorithms came from," says Holland. "I began to wonder if you could breed programs the way people would, say, breed good horses and breed good corn."

Holland wrote his first paper on "adaptive algorithms" in 1962. But it

Bent Is Better

For an experimental trio of miniature satellites, NASA needed antennas with both a wide beam and a wide bandwidth. The Evolvable Systems Group at NASA Ames Research Center created evolutionary software that generated random antenna designs, simulated the antennas' behavior, and recombined features of the best performers. The result, after many generations: the bizarrely twisted design on the far right.



First Generation

wasn't until the late 1970s that he and his graduate students had amassed the computational resources to put the idea into play. Holland credits one of his students, Edward Codd, with convincing his former employer, IBM, to sell the Michigan research group a low-cost mainframe. (Codd would go on to win the A. M. Turing Award, computer science's equivalent of the Nobel Prize, for designing the first relational databases.) Even then, however, the computer's paltry 32 kilobytes of memory limited the size and scope of the researchers' initial experiments.

One of the first scientists to give evolutionary algorithms a serious test drive was Goldberg, who worked under Holland as a PhD student in the early 1980s. Goldberg resurrected a problem that he had faced during his days in the natural-gas industry: minimize the power consumption of a long-distance pipeline, given variations in regional demand. His evolutionary algorithms yielded solutions as efficient as those produced by the existing fluid mechanics software used by pipeline designers. But as Goldberg fed his algorithms bigger and more complicated problems, they began to stumble: they got stuck exploring evolutionary dead ends or spitting out hopelessly wild solutions. "I understood the problems I was solving better than the tools I was using to solve them, and that bothered me," Goldberg says.

Goldberg focused his dissertation and then another half-decade of work on making genetic algorithms more predictable. He found that adjusting the parameters of each new algorithm—the starting population size or the rate of mutation, for example—smoothed out a few wrinkles. But for the most part, his research left him with a sobering realization: evolutionary algorithms were often more complex than the problems they tried to solve. Eventually, Goldberg learned to steer clear of what he calls "needle in the haystack" problems, which demand a single, best solution; these tended to cause evolutionary algorithms to spin out of control. Instead, he aimed at friendlier problems that had a range of viable solutions, depending on how you approached them. "If there are dozens of needles scattered around in such a way that the [evolutionary algorithm] can break the haystack down into smaller haystacks, you at least guarantee yourself a shot at a better outcome," Goldberg says.

Goldberg documented his work in a 1989 textbook, a volume that would inspire other computer-savvy engineers to begin their own tinkering. By the mid-1990s, engineers at General Electric Research Center in Niskayuna, NY, had built evolutionary methods into an in-house design tool called EnGENEous, which was used to find the most efficient shape for the fan blades in the GE90 jet engines used on Boeing's 777 aircraft. EnGENEous allowed the GE90 team to eliminate one stage of the engine's compressor, which meant a reduction in engine weight and manufacturing costs without any sacrifice in aerodynamic performance. "After this initial success, the floodgates opened to use these types of tools in many different applications across all of GE's businesses," says Pete Finnigan, laboratory manager for advanced mechanical-design applications at the research center. Engineers at Rolls Royce, Honda, and Pratt and Whitney have followed suit, incorporating genetic algorithms into their own design processes.

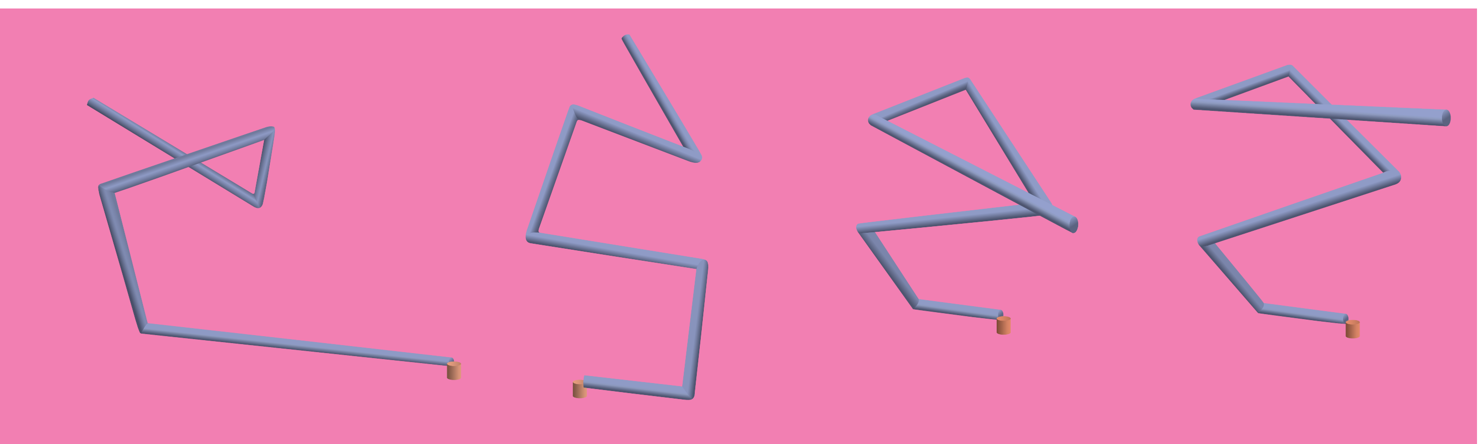
Flagging Fraud

But while computers have grown powerful enough to apply evolutionary principles to all sorts of problems, the "haystacks" have been multiplying at an even more dramatic rate. Consider consumer fraud. Credit card companies estimate that \$.07 per \$100 charged to credit cards is lost to fraud, costing the industry more than \$1 billion per year in the United States alone. Yet writing traditional software to identify fraudulent charges remains phenomenally difficult. Why? Because the people perpetrating the fraud are experts at modifying their behavior to evade detection. It's simply not possible to write a program that anticipates every possible scam.

But evolutionary algorithms can at least make computerized fraud detection more likely to succeed, argue the artificial-intelligence researchers who founded New York City–based Searchspace. The company sells a variety of programs that split up the haystack by looking for aberrant activity within precisely defined slices of existing account data, says Michael Recce, Searchspace's chief scientist. The software uses tools dubbed "sentinels," programmed with fraud detection rules. Multiple charges to the same debit card at a single store on a single day, for example, might automatically raise a red flag.

But the person racking up these purchases may simply be a forgetful Christmas shopper, not a thief. So the sentinels

JASON LOHN, NASA AMES RESEARCH CENTER



Middle Generation

Last Generation

weigh in a variety of factors, such as a person's prior activity at that store, in order to avoid "false positives" and flag only accounts that human experts would agree are suspect. Says Recce, "You can set the fitness criteria in a way that delivers both minimal fraud loss and minimal good-customer loss."

Searchspace routinely hosts "pilots," essentially software bake-offs that pit its algorithms against potential clients' existing fraud detection systems. Participants bring in blind samples of historical data to see if Searchspace's sentinels plant red flags in all the right places. Invariably, says Recce, the sentinels turn up not only the preflagged accounts but also a few more miscreants lurking in the background noise. "I don't think there's been one of those presentations where we haven't had to pause things for a moment so that an executive could go step out to make a quick phone call," says Recce, smiling.

Helping Businesses Evolve

Ascent Technologies, Cambridge, MA
Ascent developed the SmartAirport Operations Center, which uses evolutionary algorithms to coördinate airport operations such as gate and ground traffic, baggage routing, and security staff scheduling.

Deere and Company, Moline, IL
The famous maker of John Deere tractors and lawnmowers uses evolutionary algorithms to breed assembly line schedules that best meet projects' cost, time, and safety requirements.

First Quadrant, Pasadena, CA
Evolutionary algorithms developed by Santa Monica, CA, think tank Rand have helped this hedge fund time stock trades and other investment decisions. First Quadrant has used evolutionary models to manage up to $6 billion in capital.

Nutech Solutions, Charlotte, NC
Nutech's evolutionary algorithms help General Motors make more money on automobile resales by suggesting the best times, locations, and prices at which to sell vehicles, given regional variations in auction prices, transportation costs, and the like.

Schlumberger, New York, NY
Software from the giant oil-field-services company uses evolutionary algorithms to help oil drillers decide when to drill new wells, based on the production of existing wells.

Patently Original

Now that evolutionary algorithms are outwitting humans, some researchers want to raise the bar even higher. At Stanford University, for example, professor of biomedical informatics John Koza—yet another Holland protégé—is exploring a closely related field called genetic programming. Evolutionary algorithms have fixed sets of instructions and merely vary the data they manipulate. Genetic programs are more like sexual organisms, capable of improving over time by shuffling bits of code among themselves. The "discoveries" made so far by Koza's programs range from novel computerized methods for sorting proteins to cutting-edge designs for electronic circuits.

Evolved designs can be unintelligible. But if they actually work, does it matter if we don't understand how?

The circuit designs emerged from Koza's work with Matthew Streeter of Carnegie Mellon University and Martin Keane of Econometrics, a marketing strategy consultancy based in Chicago. Together, the researchers built a program that draws schematic circuit diagrams. Their first challenge was to see whether the genetic approach could derive from scratch circuit designs already patented by past engineers. The program had little trouble generating simple designs that matched those patented in the 1930s and 1940s. Indeed, Koza began referring to the program as an "invention machine" and created a Web page that tracks the latest discoveries by "human competitive" software.

By the time Koza's group tested the fourth or fifth versions of their program, however, something even more surprising began to happen: the program kicked out circuit designs unpublished anywhere in the patent literature. Two of these designs—a pair of controller circuits that regulate feedback—were so original that Koza and his colleagues have taken out patents on them.

As proud as he is of his software, Koza isn't about to assign responsibility for the new designs to the program itself. The patents credit Keane, Koza, and Streeter, in that order. But there are a few new pseudophilosophical conundrums lurking here: If something is invented with no human near, is it really an invention? Who is the inventor? And if the invention actually works, does it matter if we don't understand how?

On that last point, says NASA's Lohn, "There are two schools of thought. One says I just need something that does X, Y, and Z, and if evolution gives me X, Y, and Z, that's all I care about. The other school wants to know what's in there and how it works. We can't really help those people, because we frequently see evolved designs that are completely unintelligible."

There's no need yet for humans to feel jealous of "human competitive" software, says Koza, since the ultimate goal is simply to hand over engineering's hardest drudge work to computers. He does foresee a time in the near future—perhaps 20 years from now—when genetic algorithms running on ultrafast computers will take over basic design tasks in fields as diverse as electronics and optics. But even then, Koza believes, human and machine intelligence will work in partnership. "We've never reached the place where computers have replaced people," Koza says. "In particular narrow areas, yes—but historically, people have moved on to work on harder problems. I think that will continue to be the case." ■

Sam Williams is a freelance technology writer based in Staten Island, NY. He is a frequent contributor to Salon.

DR. NANOTECH VS. CANCER

James Heath has a better way to fight cancer: tiny silicon wires that could sniff out early signs of the disease.

By Philip Ball

PHOTOGRAPH BY JOE TORENO

IF YOU ARE AMONG THE THIRD OF THE POPULAtion who will someday develop cancer, your body will contain warning signs well before your doctor is able to diagnose the disease. If these subtle signals in your cells and your bloodstream could only be detected sooner, you'd have a far greater chance of surviving. The problem is that the changes that mark the early stages of cancer are remarkably complex—and often slight, even on a molecular level.

But James Heath, a physical chemist at the California Institute of Technology, believes that nanotechnology could finally provide the solution to this molecular riddle. Heath is betting that banks of ultrasmall silicon wires, each made to detect a specific cancer-related protein, could pick up even the most subtle changes in our body chemistry. The nanosensors that Heath and his Caltech coworkers are developing will simultaneously look for hundreds or even thousands of different biomolecules in, say, a drop of blood. If they work, these nanosensors could be the basis for cancer tests that are not only more accurate but, because they don't involve tissue sampling and lab analysis, cheaper and more convenient than those now available.

That's not saying much, of course. Screening for most cancers remains primitive, often involving simple physical exams to find evidence of tumor growth, or crude imaging methods such as mammography and x-rays. Blood tests exist for a few cancers, such as prostate and ovarian cancers, but their performance is woeful; not only are they slow and costly, but they're notoriously unreliable. To diagnose prostate cancer, for example, doctors look for a protein called PSA (prostate-specific antigen) in the blood. But only 25 to 30 percent of men who go through the immensely stressful process of having tissue biopsies because of high PSA levels in their blood actually have prostate cancer. "PSA is always in the prostate," points out Heath, "and is leaked out into the blood in small quantities all the time. When there is some sort of trauma to the prostate—which could be cancer or something else—it leaks out in greater quantities. But it is a very poor marker for early-stage prostate cancer, since there really isn't too much trauma to the prostate at that stage."

A more accurate cancer test would better reflect the complexity of biomolecular events. Heath's ambition is to construct devices that can not only make multiple measurements at once, from a drop of blood or a few cells taken from a particular tissue, but also detect extremely small quantities of biomolecules. "We are trying to develop a finger prick–based test," he explains. "We would like this test to eventually be something analogous to what is used for diabetics. Diabetics can now monitor their glucose levels, and because they can do that on a regular basis, they take control of the disease. We would like to develop a similarly enabling platform for cancer."

Piecing Together the Puzzle

Cancer research might seem an unlikely place for James Heath to have ended up. As a graduate student at Rice University in Houston during the early 1980s, he began studying the properties of tiny chunks of materials. He was part of the team that, in 1985, discovered the soccer ball–shaped carbon molecule C_{60}; the discovery won Heath's professor, Richard Smalley, a Nobel Prize 11 years later and helped launch today's interest in nanotech. But Heath later shifted his focus to semiconductors, such as silicon, used by the microelectronics industry, looking for ways to fashion them into ever smaller devices. Recently, he and collaborators at the University of California, Santa Barbara, devised a method for making silicon wires just a few nanometers wide, about ten times smaller than the smallest features in today's integrated circuits.

The advance was a milestone in the continued miniaturization of electronics. And, says Heath, "We hoped that by solving such a difficult problem, other opportunities would present themselves." They did: Heath realized these nanowires could also serve as ultrasensitive biosensors.

He also realized, however, that incorporating nanowires into an effective diagnostic tool would not be easy. Changes in a person's state of health are reflected in wild swings in concentrations of biomolecules as different genes switch on and off. But over the past several years, geneticists and molecular biologists have come to realize that genes don't generally act independently. They tend to operate in groups and networks, and they can regulate each other's expression. So making sense of the molecular "fingerprints" of disease requires a systems-level understanding of how genes and proteins work together.

That's where Heath's collaborator, Leroy Hood, founder of the Institute for Systems Biology in Seattle, comes in. Systems biologists look at the cell much as an electrical engineer looks at a complex circuit: as a highly interconnected system of components that switch each other on and off and relay signals. Heath's sensors might provide thousands of clues to a person's state of health, but Hood's systems-biology approach is needed to piece all those bits of information together into a coherent picture.

Hood and his team have, for example, looked at how genes are expressed to produce proteins in cells and tissues affected by prostate cancer. "Our idea," says Hood, "is that the difference between normal and diseased cells is that the protein and gene regulatory networks in diseased cells have been perturbed, and these disease perturbations are reflected in altered patterns of protein expression controlled by the networks. A fraction of these perturbed proteins will find their way into the blood and constitute molecular fingerprints that are diagnostic not only of health and disease but of what disease and what type of a particular disease." (There are at least three different types of prostate cancer, for example.)

"We have identified 300 [cancer marker] genes that are uniquely expressed in the prostate," says Hood, "and we predict that about 62 of these may be secreted into the blood. We tested one of these by making antibodies against it and demonstrated that it was only present in the blood of patients with prostate cancer." Hood's team is now testing five more prostate cancer–secreted proteins. It has also found a similar array of genes that should be diagnostic for ovarian cancer.

The diagnosis of cancer will be "carried out automatically, in a few seconds or minutes, on just a handful of cells or their contents."

A Fluid Situation

What exactly would a nanosensor to detect such proteins look like? To turn a nanowire into a transistor, the researchers bring each of its ends into contact with metal wires so that a current can be passed through it. They then position an electrode close to the nanowire. Charging this electrode alters the conductivity of the nanowire, turning it "on" and "off"—all familiar stuff to any electrical engineer.

Heath then transforms his nanowire transistors into tiny biosensors. Say, for instance, that one nanowire is to act as a sensor for a particular protein. The researchers coat the surface of the wire with antibodies that will stick to the target protein but not to other molecules. When proteins bind to the antibodies, they interact with the electrons traveling in the nanowire's surface layer, altering its conductivity. If the wire is only a few nanometers thick, there is a significant—and measurable—change in its overall conductivity. "If the wire is really, really small," says Heath, "instead of putting a voltage on it, we can put molecules on it, and a chemical event is what causes the transistor to switch."

Their small size also makes the devices very sensitive. Ultimately, the number of molecules required to produce a reading will depend on how tightly they bind to the receptor groups on the sensor surface; but it might be possible to detect individual molecules. Heath says that, although his group has not yet reached that level of sensitivity, it has succeeded in detecting just a few molecules. (Charles Lieber of Harvard University, meanwhile, has demonstrated nanosensors that can detect a single viral particle*. See "Supersensitive Screen, p. 85).

But it's not just high sensitivity that Heath is relying on for easy and early detection of disease. "We can make thousands of these sensors in a very small area," he says. This means the ability to screen the varied molecular contents of individual cells. Heath is collaborating with Stanford University microfluidics expert Stephen Quake to fabricate chips in which fluids pumped down microscopic channels shuttle single cells into position over a nanosensor array, where they can be studied one at a time.

In the end, all this technology has to be integrated in a device that can be used in the clinic, which means solving yet more technical and practical problems. In 2003, the Institute for Systems Biology, Caltech, and the University of California, Los Angeles, established the NanoSystems Biology Alliance to ensure that the new tools reflect the latest advances in cancer biology and immunology. The diagnosis of cancer and other diseases, says Quake, will be "carried out automatically, in a few seconds or minutes, on just a handful of cells or their contents." And that conjecture, he predicts, "will be turned into a reality within this decade." ■

Philip Ball's latest book is called Critical Mass: How One Thing Leads to Another.

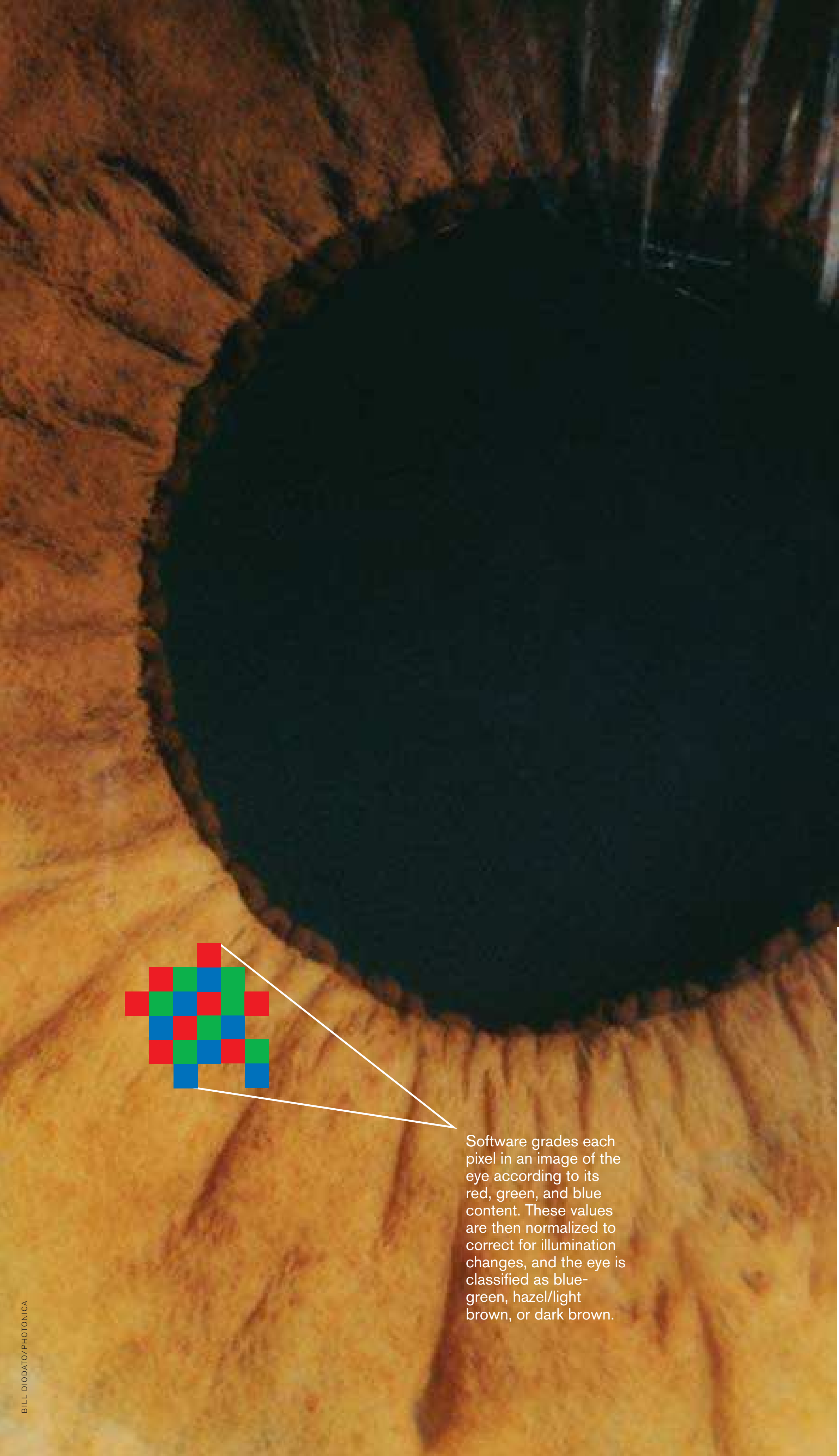
* **WWW.TECHNOLOGYREVIEW.COM** To see how Charles Lieber's nanowire biosensors work, visit our website and enter keyword **nanosensor**.

By Robert Buderi
PHOTOGRAPHS BY DENNIS KLEIMAN

Demo

ME, MYSELF, AND EYE

Fingerprinting, iris scans, and face recognition may be cutting-edge identification technologies, but none alone is foolproof. At Michigan State University, Anil Jain seeks to dramatically improve security with three prototype systems that fuse several types of biometrics.



Software grades each pixel in an image of the eye according to its red, green, and blue content. These values are then normalized to correct for illumination changes, and the eye is classified as blue-green, hazel/light brown, or dark brown.

BILL DIODATO/PHOTONICA

Soft Biometrics

Data such as height, gender, ethnicity, and eye color can't establish a person's identity, but measuring these "soft" traits can enhance the accuracy of primary biometrics such as fingerprinting and face recognition. In one of Jain's systems, a pair of cameras gauges a subject's height. A close-up is then taken of her face (left), and software analyzes it to determine her gender and eye color and classify her ethnicity as either Asian or non-Asian. This data is then combined with that from a primary biometric.

3-D Face Recognition

Most face recognition systems use 2-D images and can be foiled by changes in illumination, head position, and expression. Here, a camera snaps a picture (left) of a subject as a laser scans her face, making a precise depth measurement at each point (right). The system next tries to match the depth image to a 3-D model stored in a database, but it also performs conventional 2-D face recognition for corroboration.

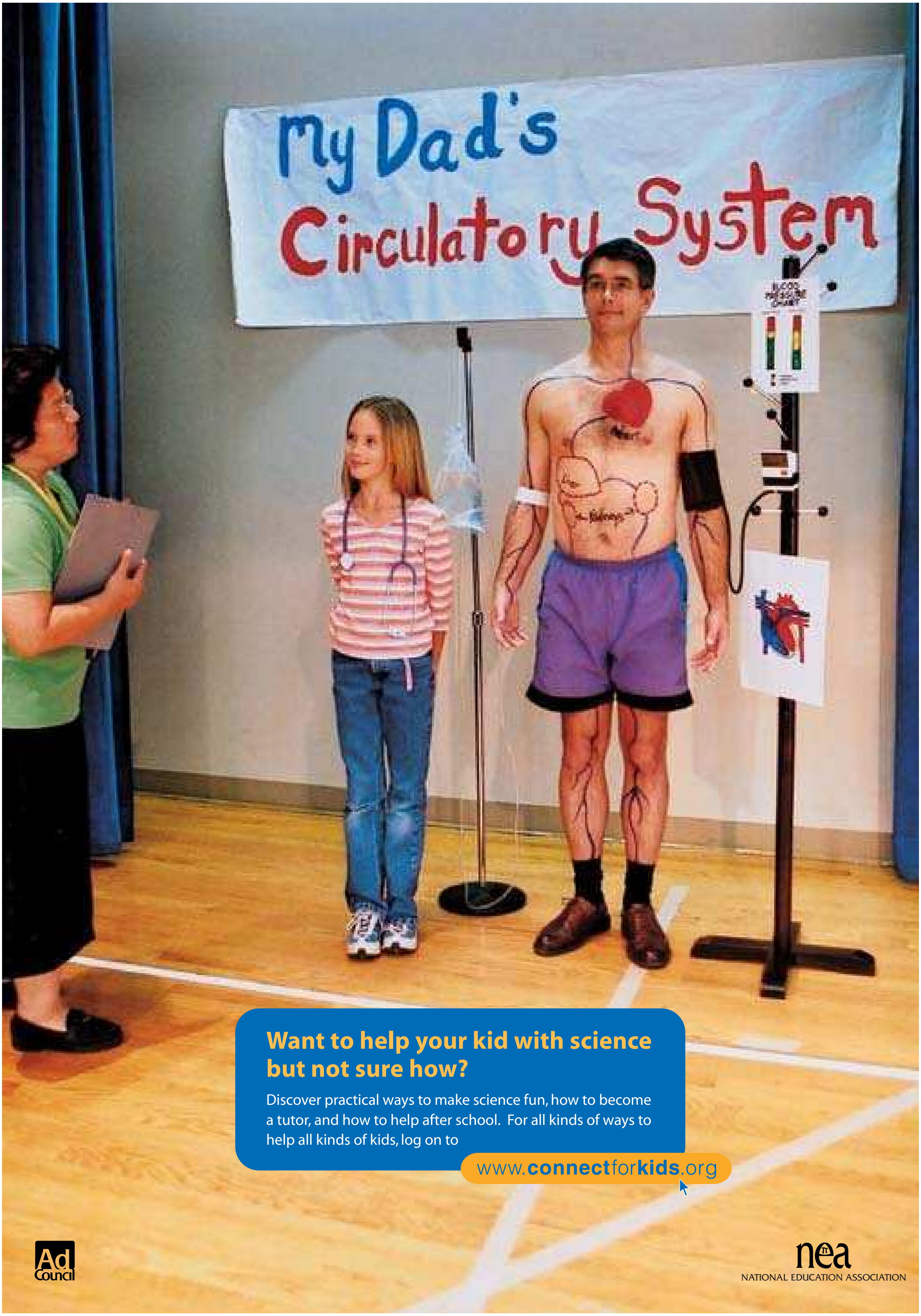
The system uses information about "anchor points" such as the tip of the nose and corners of the eye to conduct a preliminary search of database images. A proprietary algorithm then performs a finer-grained comparison. Because it captures surface geometry, the 3-D system works independently of lighting changes and head position.

Fingerprint-matching algorithms gauge the position and directionality of minutiae (right) and other features that make a fingerprint distinct.

ELINOR CARUCCI/PHOTONICA

Hand to Mouth

Jain's third system combines hand geometry, face recognition, and fingerprint matching. A subject places her hand on a pad (not shown) that measures 14 aspects of hand geometry, including the width of the palm and the length and width of each finger. The system then performs a conventional 2-D face recognition match. Finally, a fingerprint analysis is performed. Most systems check the same finger every time. But fingerprints can be forged. Jain is contemplating systems that record data on all ten digits and randomly ask to scan one or more.



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Megascope Ed Tenner

Keeping Tabs

The history of an Information Age metaphor

How many college students today ever flip through trays of library catalogue cards? Some of them may never have used an actual tabbed file. But the tab as an information technology metaphor is everywhere in use. And whether our tabs are cardboard extensions or digital projections, they all date to an invention little more than a hundred years old. The original tab signaled an information storage revolution and helped enable everything from management consulting to electronic data processing.

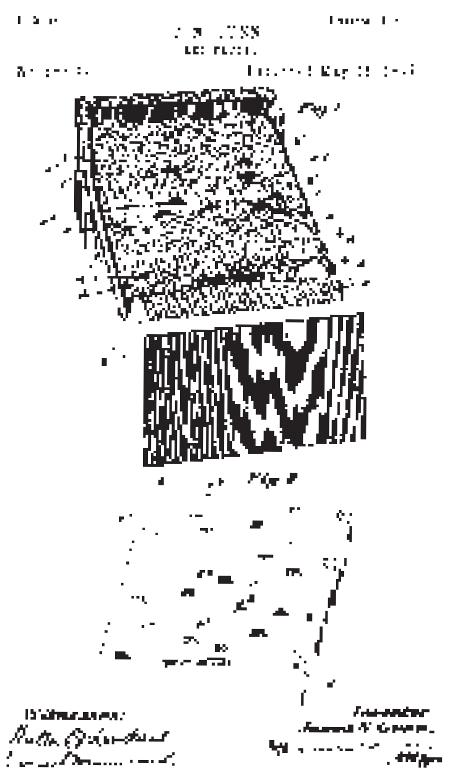
The tab's story begins in the Middle Ages, when the only cards were gambling paraphernalia. Starting in the late 14th century, scribes began to leave pieces of leather at the edges of manuscripts for ready reference. But with the introduction of page numbering in the Renaissance, they went out of fashion.

The modern tab was an improvement on a momentous 19th-century innovation, the index card. Libraries had previously listed their books in bound ledgers. During the French Revolution, authorities divided the nationalized collections of monasteries and aristocrats among public institutions, using the backs of playing cards to record data about each volume.

The idea of a randomly accessible, infinitely modifiable arrangement of data flowered first in the United States. Not that America had more books to organize. In 1820, the Göttingen University library in Germany already had 200,000 volumes; Harvard University had fewer than 118,000 books in 1861, when it became the first major library to use cards. The historian John Higham called the catalogue a "revolutionary" and characteristically American tool, which promoted specialization by grouping authorities together under topic headings and integrated the latest books rapidly—features we take for granted now.

It took decades to add tabs to cards. In 1876, Melvil Dewey, inventor of decimal classification, helped organize a company called the Library Bureau, which sold both cards and wooden cases. An academic entrepreneur, Dewey was a perfectionist supplier. His cards were made to last, made from linen recycled from the shirt factories of Troy, NY. His card cabinets were so sturdy that I have found at least one set still in use, in excellent order. Dewey also standardized the dimension of the catalogue card, at three inches by five inches, or rather 75 millimeters by 125 millimeters. (He was a tireless advocate of the metric system.)

Even the Library Bureau did not offer a convenient way to separate groups of cards, apart from thin metal partitions that wrapped around them, or taller cards. The tab was the idea of a young man named James Newton Gunn (1867–1927), who started using file cards to achieve savings in cost accounting while working for a manufacturer of portable forges. After further experience as a railroad cashier, Gunn developed a new way to access the contents of a set of index cards, separating them with other cards distinguished by projections marked with letters of the alphabet, dates, or other information.



Gunn's background in bookkeeping filled what Ronald S. Burt, the University of Chicago sociologist, has called a structural hole, a need best met by insights from unconnected disciplines. In 1896 he applied for a U.S. patent, which was granted as number 583,227 on May 25, 1897. By then, Gunn was working for the Library Bureau, to which he had sold the patent. It was to be a perfect match. The Bureau was becoming a leading supplier of corporate record-keeping equipment, offering "commercial grade" cards on wood-pulp stock.

The Library Bureau also produced some of the first modern filing cabinets, proudly exhibiting them at the World's Columbian Exposition in Chicago in 1893. Files had once been stored horizontally on shelves. Now they could be organized with file folders for better visibility and quicker access. Tabs were as useful for separating papers as for organizing cards. Since business people were unfamiliar with the new technology, Library Bureau staff provided consulting services as well as equipment and supplies. By 1913, the company was advertising in the New York *Times* that it could supply a credit department with a 16-by-16-by-20-inch cabinet to "keep tab" on up to 14,000 customers. The Library Bureau also worked with Herman Hollerith, whose electrical punch card system later became the foundation of IBM.

James Newton Gunn went on to found one of the first consulting firms focusing on industrial engineering. He became an automotive and rubber industry executive. He helped found Harvard Business School and lectured at MIT, among other places. But the tab is his lasting legacy. And it is ubiquitous: in the dialogue boxes of Microsoft Windows and Mac OS X, at the bottom of Microsoft Excel spreadsheets, at the side of Adobe Acrobat documents, across the top of the Opera and Firefox Web browsers, and—even now—on manila file folders. We've kept tabs. ■

Reviews

Our reviews use any artifact—
a book, a product, a government report,
a movie, a research paper—
as the occasion for a
contemplative essay on some
technological controversy.

The Unobservable Mind

One of Britain's leading philosophers is skeptical that neurobiology can tell us anything about self-consciousness.

BY ROGER SCRUTON

CONSCIOUSNESS IS MORE familiar to us than any other feature of our world, since it is the route by which anything at all becomes familiar. But this is what makes consciousness so hard to pinpoint. Look for it wherever you like, you encounter only its objects—a face, a dream, a memory, a color, a pain, a melody, a problem, but nowhere the consciousness that shines on them. Trying to grasp it is like trying to observe your own observing, as though you were to look with your own eyes at your own eyes without using a mirror. Not surprisingly, therefore, the thought of consciousness gives rise to peculiar metaphysical anxieties, which we try to allay with images of the soul, the mind, the self, the "subject of consciousness," the inner entity that thinks and sees and feels and that is the real me inside. But these traditional "solutions" merely duplicate the problem. We cast no light on the consciousness of a human being simply by redescribing it as the consciousness of some inner homunculus—be it a soul, a mind, or a self. On the contrary, by placing that homunculus in some private, inaccessible, and possibly immaterial realm, we merely compound the mystery.

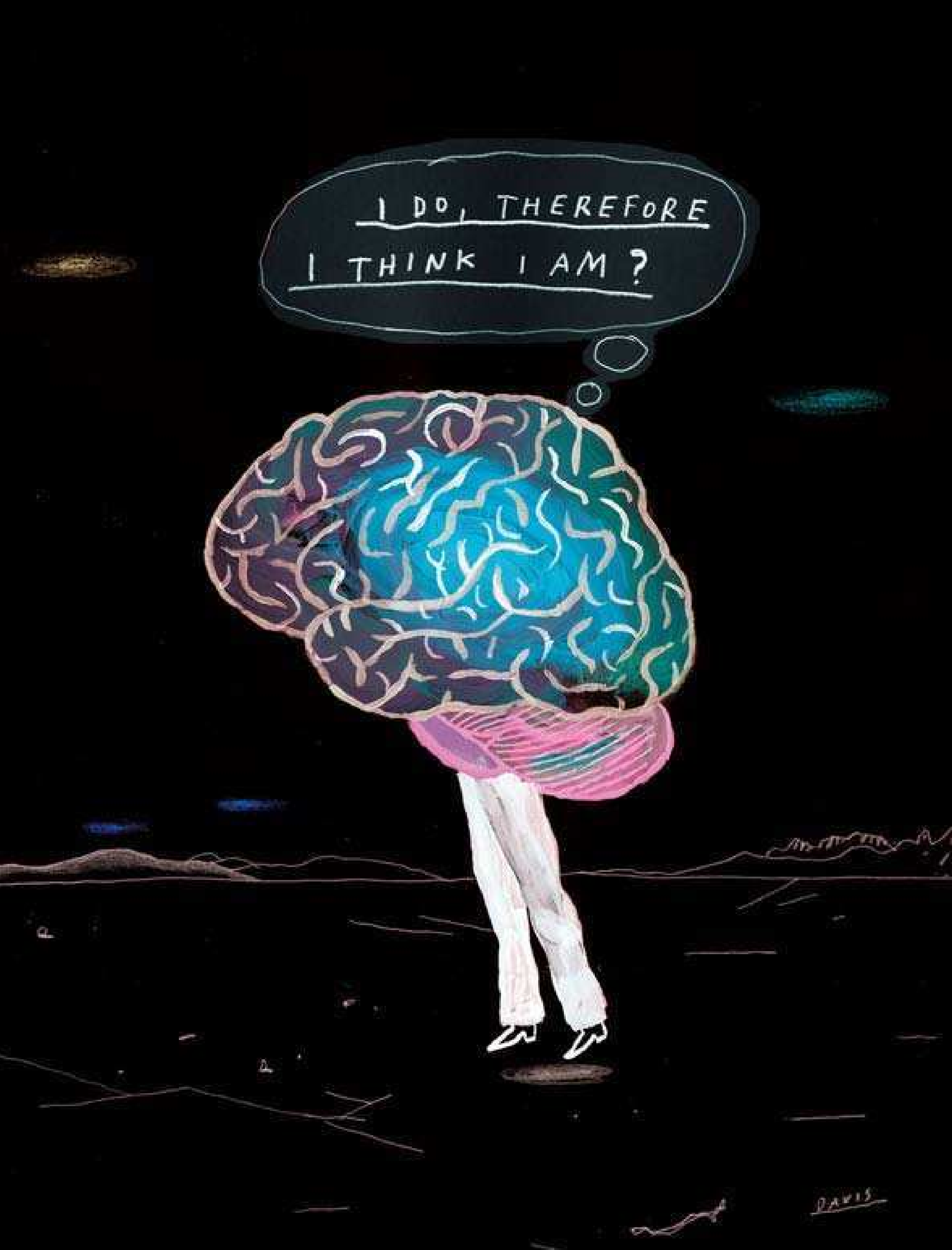
Putting the point in that way makes it clear that, in the first instance at least, the problem of consciousness is a philosophical, not a scientific, problem. It cannot be solved by studying the empirical data, since consciousness (as normally understood) isn't one of them. We can observe brain processes, neurons, ganglions, synapses, and all the other intricate matter of the brain, but we cannot observe consciousness. I can observe you observing, but what I observe is not that peculiar thing that you know from within and that is present, in some sense, only to you. At least, so it would seem; if this is some kind of mistake, it is a philosophical and not a scientific argument that will tell us so.

> ### The Mind's I
> **The Quest for Consciousness: A Neurobiological Approach**
> By Christof Koch
> Roberts, 2004, $45.00

This appropriation of the question by philosophy is apt to make scientists impatient. Surely, they will argue, if consciousness is real it must be part of the real world—the world of space and time, which we observe with our senses and explain by science. But what part? First-person reports of conscious states are radically affected by brain damage, and the behavior that leads us to describe others as conscious originates in the nervous system, whose functions seem to be largely controlled by the brain. Common sense and scientific inference therefore both point to the brain as the seat of consciousness. So, scientists argue, let's study the brain and find out exactly which of its processes correspond to our conscious mental states. That way, they suggest, we will find out what consciousness is.

But will we? Unfortunately, the philosophical problem comes back at us in another form. How exactly do we discover a correspondence between consciousness and a brain process, given that consciousness is not something that we observe? And sup-

PAUL DAVIS


I DO, THEREFORE
I THINK I AM?
DAVIS

pose we overcome that difficulty and produce a theory correlating conscious mental states with specific neurological events. This means that we have discovered what consciousness *is* only if we can advance from this correspondence to an understanding of our identity. And that is precisely what so many philosophers doubt we can do. True, there are some who defend the view that conscious states are identical with brain processes, but they defend it on philosophical, not scientific, grounds. And their view is open to radical objections: for example, how can a state of one thing (a person) be identical with a process in another (a brain)?

If the neurobiologist Christof Koch, professor of cognitive and behavioral biology at Caltech, enters this territory with some trepidation, he nevertheless hopes to take possession of it in the name of science. The task, he believes, is to avoid getting lost in definitions and conceptual puzzles and instead to discover the "neuronal correlates of consciousness." He at once narrows that target, however, to "the minimal set of neuronal events and mechanisms jointly sufficient for a specific conscious percept." In other words, the object of study is not consciousness as such but "specific conscious percepts," in particular those involved in visual perception. Koch's ambition, nevertheless, is to integrate the analysis of vision into the more general program that he developed with the late Francis Crick, one of the discoverers of the structure of DNA, who contributes the foreword to the book. That program is to explain how consciousness evolved and identify the processes in the brain that carry it. The book gives a fairly comprehensive account of what neurobiology has to say about the higher functions of the brain. It is not surprising, therefore, that the writing is densely scientific and heavily referenced, with many digressions. But proceeding on the supposition that the science is correct, what do we make of the title? Does neurobiology in the style of Crick and Koch really take us further in the "quest for consciousness"? Or is it simply amassing more and more information about the brain, without telling us how brain and mind are connected?

First Person Singular

One of the problems, which constantly intrudes on Koch's argument but is never resolved, is that conscious mental states do not belong to a single category. We assume that all sensations are conscious (there is no such thing, for example, as unconscious toothache), that there is both conscious and unconscious thought, and that while desire may be unconscious, intention never is. But what do conscious mental states have in common? At times Koch seems to suggest that they are all "felt" by the subject, or that they each possess a particular subjective quality or "quale" that is observable only to the subject. But we don't feel our thoughts, and there is no subjective quale that distinguishes the belief that two plus two is four from the belief that three plus three is six, or the intention to sit down to supper from the intention to eat a steak. In the case of language-using creatures, we distinguish conscious from unconscious mental states through the "first-person" perspective. A state is conscious if the subject can truly confess to it, without having to carry out an investigation and on no basis other than understanding the words that he uses. Hence in other places Koch seems to take the first-person case as characteristic of consciousness, a procedure that deprives him of a clear basis for attributing consciousness to animals, who never confess to their mental states because they never confess to anything. This is serious, since the science on which Koch draws derives from examining the brains of mice and monkeys.

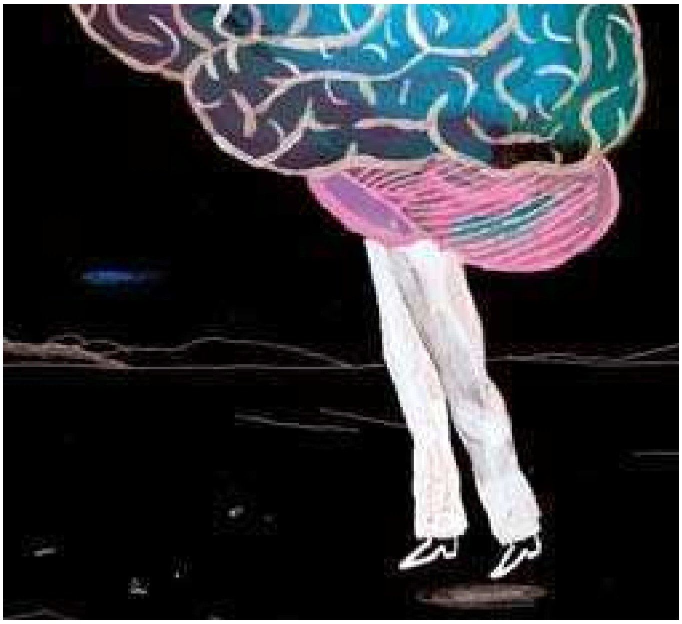
Crucial to the Koch-Crick approach is a thought experiment involving the idea of the unconscious zombie. This is a creature all of whose behavior issues by reflex action, mediated by the cortex, but who is not conscious of what he is doing. This creature feels nothing, has no inner "qualia" and—presumably—no first-person awareness of his own mental states. So what else does he lack? Or can he be exactly like us and lack *only* those things? Koch is of the view that a zombie would lack the capacity to plan for the future or to deal with multicontingency situations where complex choices must be made. Plotting, planning, and deciding, he says, are among the important *functions* of consciousness and point to a Darwinian explanation of why consciousness exists.

Such an argument will help in the "quest for consciousness" only if we can show how "feeling," "qualia," and the "first-person case" are connected to plotting and planning. If the connection is only contingent, then a zombie could possess all the functions of consciousness without the feelings. If the connection is necessary, then it must be established in some way other than by scientific inference. As it is, the reader is left at the end of Koch's book with the puzzle with which it began: granted that there are neuronal correlates of consciousness, what exactly are they correlated *with*? And what exactly do we mean by "correlation"?

To answer that question, I would suggest first that we dismiss the idea of purely subjective "qualia." The belief that these essentially private features of mental states exist, and that they form the introspectible essence of whatever possesses them, is grounded in a confusion, one that Wittgenstein tried to sweep away in his arguments against the possibility of a private language. When you judge that I am in pain, it is on the basis of my circumstances and behavior, and you could be wrong. When I ascribe a pain to myself, I don't use any such evidence. I don't find out that I am in pain by observation, nor can I be wrong. But that is not because there is some *other* fact about my pain, accessible only to me, which I consult in order to establish what I am feeling. For if there were this inner private quality, I could misperceive it; I could get it wrong, and I would have to *find out* whether I am in pain. To describe my inner state, I would also have to invent a language, intelligible only to me—and that, Wittgenstein plausibly argues, is impossible. The conclusion to draw is that I ascribe pain to myself not on the basis of some inner quale but on no basis at all.

Of course, there is a difference between knowing what pain is and knowing what pain is *like*. But to know what it is like is not to know some additional inner *fact* about it, but simply to have felt it. We are dealing with familiarity rather than information. While one philosopher—Thomas Nagel, a professor at New York University and author of *The View from Nowhere*, a fascinating study of subjectivity—has placed great emphasis on the "what it's like" idea, suggesting that it describes a distinctive mark of conscious experience, the idea remains opaque to further analysis. "What it's like" is not a proxy for a description but a refusal to describe. We can spell it out, if at all, only in metaphors. Q: "What's it like, darling, when I touch you there?" A: "Like the taste of marmalade, harmonized by late Stravinsky."

Similarly, we are not going to get very far in understanding



The subject is in principle unobservable to science, not because it exists in another realm, but because it is not part of the empirical world. It lies on the edge of things, like a horizon.

consciousness if we concentrate on the idea of "feeling" things. For there are conscious mental states that have nothing to do with feeling. We feel our sensations and emotions, certainly, just as we feel our desires. All of those mental states would once have been classified as passions, as opposed to mental actions–thought, judgement, intention, deduction–which are not felt but done. I can deliberately think of Mary, judge a picture, make a decision or a calculation, even imagine a centaur, but not deliberately have a pain in the finger, a fear of spiders, or a desire for more cake. Even if I could have a pain by willing it, or if I manage to suppress my desires, this does not mean that pains and desires are actions, but only that they are passions that I can affect through mental discipline, like a yogi might reduce his heart rate. Moreover, there are psychologists and philosophers who seem quite happy with the idea of "unconscious feelings." We may balk at the expression, but we know what they mean. It is possible to feel something without being conscious of the feeling. Feeling is a mark of consciousness only if we interpret "feeling" as "awareness." But what is it to be aware of something? Well, to be conscious of it.

Emergent Properties

How do we fight ourselves free from this tangle of circular definitions and misleading pictures? Two ideas seem to me especially helpful in explaining our sense of consciousness as a realm apart. The first is that of an emergent property. Mental states generally, and conscious states in particular, can be seen as emergent states of organisms. A useful analogy is the face in a picture. When a painter applies paint to a canvas, she creates a physical object by purely physical means. This object is composed of areas and lines of paint, arranged on a surface that we can regard, for the sake of argument, as two dimensional. When we look at the painting, we see a flat surface, and we see those areas and lines of paint, and also the surface that contains them. But that is not all we see. We also see a face that looks out at us with smiling eyes. In one sense, the face is a property of the canvas, over and above the blobs of paint; you can observe the blobs and not see the face, and vice versa. And the face is really there: someone who does not see it is not seeing correctly. On the other hand, there is a sense in which the face is not an additional property of the canvas, for as soon as the lines and blobs are there, so is the face. Nothing more needs to be added in order to generate the face–and if nothing more needs to be added, the face is surely nothing more. Moreover, every process that produces just these blobs of paint, arranged in just this way, will produce just this face–even if the artist herself is unaware of the face. (Imagine how you would design a machine for producing Mona Lisas.)

Maybe consciousness is an emergent property in that sense: not something over and above the life and behavior in which we observe it, but not reducible to them either.

The second helpful thought is one first given prominence by Kant and thereafter emphasized by Fichte, Hegel, Schopenhauer, and a whole stream of thinkers down to Heidegger, Sartre, and Thomas Nagel. The idea is to draw a distinction between the subject and the object of consciousness, and to recognize the peculiar metaphysical (Wittgenstein would say grammatical) status of the subject. As a conscious subject, I have a point of view on the world. The world *seems* a certain way to me, and this *seeming* defines my unique perspective. Every conscious being has such a perspective, since that is what it means to be a subject rather than a mere object. When I give a scientific account of the world, however, I am describing objects only. I am describing the way things are, and the causal laws that explain them. This description is given from no particular perspective. It does not contain words like "here," "now," and "I"; and while it is meant to explain the way things seem, it does so by giving a theory of how they are. In short, the subject is in principle unobservable to science, not because it exists in another realm but because it is not part of the empirical world. It lies on the edge of things, like a horizon, and could never be grasped "from the other side," the side of subjectivity itself. Is it a real part of the real world? The question begins to look as though it has been wrongly phrased. I refer to myself, but this does not mean that there is a self that I refer to. I act for the sake of my friend, but there is no such thing as a sake for which I am acting. (The parallel illustrates Wittgenstein's view of these puzzles as essentially grammatical.)

We can relate to conscious creatures in ways that we cannot relate to objects. Their behavior is the outcome of the way things seem to them and can therefore be altered by altering the way things seem. Giving them "food for thought" or–in the case of more primitive animals–"food for perception" and "food for belief," we also bend them to our purposes. Because they feel pleasure and pain, they can be rewarded and punished and so taught to behave in new ways. Everybody who has trained a dog or a horse in even the simplest task knows that consciousness is an essential intermediary in achieving the final result, and that

there is nothing puzzling about this at all: consciousness is as much a part of the behavioral repertoire of the animal as eating and excreting. It consists in a set of functional connections between world and behavior, of a kind that leads us to identify a "point of view," a "way things seem" that distinguishes the creature with which we are dealing. This point of view is also the quickest and easiest channel to the springs of its behavior.

In referring to behavior, we don't have to accept the old behaviorist theory that mental predicates can simply be reduced to behavioral syndromes. When we interpret behavior as the expression of a conscious state, we are expressly situating it in an intuitively understood nexus of causal relations. The behavior of a man in pain is only superficially like the behavior of an actor who is pretending to be in pain. The sufferer really cannot stand on his injured leg, and the leg really is injured; the actor's behavior is voluntary, the sufferer's involuntary. And so on. All those judgments are hypotheses concerning the functional connections between world and behavior, and they form parts of a spontaneous theory that some philosophers have called "folk psychology."

Consciousness emerges from the total behavioral and neurological repertoire—just as the face in the painting emerges from the whole array of colored patches.

Now, there are certainly "neuronal correlates" of consciousness, so understood: namely, all the electrical processes that are necessary to generate conscious behavior (among which, according to Koch, gamma waves—oscillations recorded by an electroencephalogram in the 30- to 70-hertz domain—are particularly important). Some animals exhibit these processes; some (insects, for instance) don't. To discover the source of these processes is, in a sense, to discover the seat of consciousness in the brain. But does this bring us any nearer to knowing what consciousness is? Suppose you came across a person who behaved and talked as you did, who related to you in all the ways that people relate to each other, and who one day—to your astonishment—unzipped the top of his head to reveal nothing save a dead kitten and a ball of string. Scientifically impossible, perhaps. But logically possible, and giving no grounds at all to deny that this person was conscious.

The Unselfconscious Dog

To put the point another way, consciousness is an emergent property of organisms. But it emerges from the total behavioral and neurological repertoire, not from brain processes considered in themselves—just as the face in the painting emerges from the whole array of colored patches, not from the canvas that supports them, considered in itself. Of course, you cannot have the behavior without the brain, just as you can't have the painting without the canvas. In that sense there will be neuronal correlates of consciousness. But the discovery of these correlates does not tell us what consciousness is, nor does it solve the mystery of the subject, nor the equally perplexing mystery of the first-person case.

There is a difficulty that I have avoided, and which Koch too avoids, though incidental remarks show that he is aware of it. This difficulty arises from two radical ontological divisions in the realm of the mental. First, there is the division that separates conscious from unconscious creatures. We attribute perception of a kind to mussels and oysters—but are they conscious? Should we feel remorse when we pry open the oyster and sting its wounds with lemon juice? We are inclined to say that such organisms are too primitive to admit the application of concepts like those of feeling, belief, and desire. Maybe that goes for insects, too, however much we may admire their amazing social organization and perceptual powers.

Secondly, there is the division that separates merely conscious creatures from *self*-conscious creatures like us. Only the second have a genuine "first-person" perspective, from which to distinguish how things seem to *me* from how they seem to *you*. The creature with "I" thoughts has an ability to relate to its kind that sets it apart from the rest of nature, and many thinkers (Kant and Hegel among them) believe that it is this fact, not the fact of consciousness per se, that creates all the mysteries of the human condition. Although dogs are conscious, they do not reflect on their own consciousness as we do: they live, as Schopenhauer put it, in "a world of perception," their thoughts and desires turned outwards to the perceivable world.

The difficulty is this: we want to say of human beings that their self-consciousness is a systematic attribute of their mental life, which affects everything that they think and feel. We want to say of dogs that their consciousness is a systematic attribute of *their* mental life too, since it distinguishes them categorically from mollusks and beetles. Yet similar mental states seem to exist at all three levels. The beetle sees things; so does the dog; so does the person. How is it that one and the same mental process—visual perception—can exist in three different ontological predicaments, so to speak: as a reflex link between visual input and behavioral output, as a conscious perception, and as part of the continuous and distinguishing sense of self?

That question has led some writers (the neuroscientist Antonio Damasio in his book *Looking for Spinoza*, for instance) to think of consciousness and self-consciousness as monitoring processes—a move that comes dangerously close to the old homunculus fallacy. It is not as though my mind were just like a dog's, only with a self observing it, or a dog's just like an insect's, only with an internal monitor. Consciousness and self-consciousness are holistic properties, which emerge from the totality of a creature's physiognomy and behavior. We may discover organizations in the brain and nervous system that are biologically necessary for these features. But those "neuronal correlates" are no more likely to cast light on the mysteries of consciousness than the back of Leonardo's Mona Lisa can explain the mystery of her smile.

The conclusion to which I am tempted is not that there is no such thing as consciousness, but that there is nothing that consciousness *is*, just as there is no physical object that actually *is* Mona Lisa's smile. ■

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Reviews

How Lucent Lost It

The telecommunications manufacturer was a Potemkin village.

BY ROGER LOWENSTEIN

At the height of the great telecom bubble, Lisa Endlich reminds us, Lucent Technologies' stock was "as good as currency." Arguably, it was better than that: Lucent stock could buy whatever the company wanted. Its executives pretended that the business was growing in predictable quarterly intervals—and its investors bought the lie. So universal was the acclaim, Endlich observes in *Optical Illusions: Lucent and the Crash of Telecom*, that "the chorus of those singing Lucent's praises had almost no dissenters."

This is accurate: "almost." Indulge a brief personal memory. It is April 14, 2000, just a month after what turned out to be the peak period for the Nasdaq stock market. Sequoia Fund, a mutual fund with a conservative investment approach and on whose board I sit, is holding its annual meeting. The shareholders partake of the traditional breakfast and then retire to a banquet room overlooking Central Park to question the fund's managers.

Till now, Sequoia's resistance to popular (but pricey) stocks has been a point of pride. Its meetings have had the air of a society of devoted coreligionists for whom speculation is the cardinal sin. But over the past year, as high-tech stocks have continued to rise, Sequoia's has fallen—in part because it has refused to purchase shares in companies whose stock price is considered inflated. The natives are restive. Maybe tech stocks, they murmur, aren't so bad a buy after all?

"I've been with Sequoia for over 25 years," one of them begins, "and there's no question about it, we've done sensationally....But I'd like to be a little bit critical, if I may." Ears perk up—especially my own, since the shareholder is Bob Steinhardt, my father's cousin and always one to speak his mind.

"You've mentioned the Internet 50 times here today," Bob continues, rather sarcastically. "And there are some wonderful stocks on the Internet. I can name them for you—blue chips like AOL and Lucent. I'd like to suggest to the board and those of you up there," signaling Sequoia's managers, "that you hire an Internet/technology person."

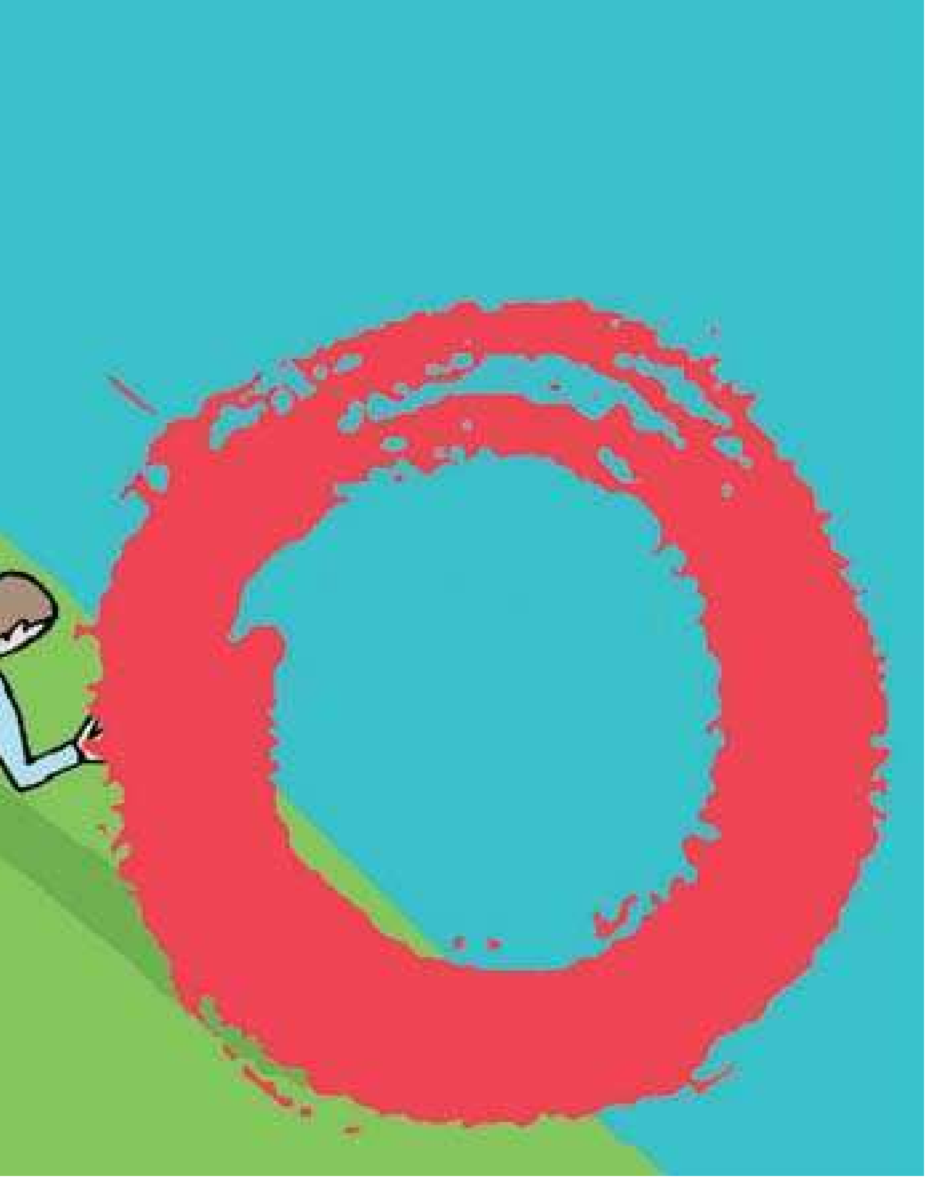
Lucent's claim to blue-chip status had spread even to Sequoia's shareholders. The company, believers argued, was not some paper dot com; 60 percent of America's telephone lines were wired to Lucent switches. Unlike Yahoo or WorldCom, Lucent was considered a "safe" new-economy stock—a businesslike distributor of digital shovels to all those high-tech miners. That was before the company lost $16 billion in a single fiscal year (2001), bid adieu to two-thirds of its staff, and, not incidentally, absorbed a decline in its stock market value of $250 billion, equivalent to 2 percent of the U.S. gross domestic product.

How did it all happen, and given the financial euphoria of the 1990s, could Lucent have done better? Internet mania was certainly beyond the company's control, but the expectations of Wall Street were not. Setting and meeting those expectations "subsumed all other goals," according to Endlich. She doesn't exactly approve of this, but she argues that, given how pervasive the bubble was, Lucent had little choice but to ride the wave. The company had to increase its stock price, or employees would depart en masse for Silicon Valley. It had to win friends on Wall Street, or it wouldn't be able to use its stock to acquire other similarly overpriced firms, as its competitors were doing. If this strategy ultimately failed, Endlich concludes, Lucent's executives cannot be faulted for lacking the clarity that "only hindsight affords." Therefore one should not be too harsh in judging their strategic blunders—for who could have foreseen the utter collapse of growth that stunned the telecommunications industry?

However, if Endlich's assessment were true—if Lucent had merely been hit by a bolt of lightning—the story would have no culprits and little to teach us. Of course, Endlich believes that Lucent's story *is* instructive. "Perhaps some light can be shed on the boom and bust at the turn of the century by adopting a micro point of view," she tentatively suggests. But though her book is

Light Reading

Optical Illusions: Lucent and the Crash of Telecom
By Lisa Endlich
Simon and Schuster, 2004, $26.95



SCOTT MENCHIN

rich in detail, she leaves it to us to determine exactly how Lucent (which means "marked by clarity" and "glowing with light") illuminates the recent period of folly.

Lucent's Four Acts of Folly

Lucent's origins were anything but dramatic. The former manufacturing arm of AT&T, it variously supplied switches and phone systems to Ma Bell, her former customers, and her offspring, the Baby Bells. It would be hard to imagine a less glamorous role than that of foot servant to a utility—and a regulated utility at that. When Lucent was spun off as an independent entity in an initial public offering in April 1996, investment bankers expected it to be a dud.

But Lucent's rebirth coincided with the deregulation of telephony and the twin revolutions of the Internet and the cell phone. Carly Fiorina, an executive noted for her steely ambition, managed the stock offering with energy and dash. Her pitches made buttoned-down institutional investors rise to their feet and applaud. Lucent was slickly marketed as the best of all possible investments—in Endlich's words, "a low-risk, high-tech company." It didn't hurt that Lucent kept the better part of Bell Labs (AT&T kept the rest), AT&T's storied but underutilized research and development wing. In the pleasing fairy tale told to Wall Street, Bell Labs, whose scientists—several Nobel Prize winners among them—had enjoyed unparalleled freedom to pursue long-term research, was to be the soul of the new Lucent. Here, the arbiters of Wall Street greedily concluded, was a large, established company whose stock was as sexy as a startup's. By the morning of the Sequoia meeting, four years after the IPO, Lucent's stock had risen nearly eightfold. Though this paled next to the performance of a stock like Qualcomm (which went up by a multiple of 50 in that timespan), the relative modesty of Lucent's ascent conferred on its shares the deceptive aura of reasonableness. It was, for a while, America's most widely held stock.

In the late 1990s, American corporations were in a state of furious transformation. Increasingly, they were governed by markets rather than by old relationships to suppliers and customers. Endlich seems to feel that Lucent was in need of a similar transformation. Noting that former AT&T hands continued to run the company, she blames much of Lucent's misfortunes on its failure to "reinvent its culture." This cliché should not go unexamined. Changing the culture was not the cure for Lucent; it was the disease. Because Lucent had long been sheltered by AT&T, once it gained its own stock, its managers felt the pressure acutely. The famously inward company became an extravert, more apt to trust in outsiders than in itself. Each of Lucent's major mistakes (I counted four) were a function of its straying from its former character.

The first goof was to abandon the Baby Bells and other traditional customers in favor of marketing to so-called competitive local-exchange carriers, or CLECs—that is, the hundreds of new phone companies spawned by deregulation. These saplings had little capital and no profits. Since they could not afford Lucent's equipment, Lucent lent them the money to buy it.

Lucent could not, on its own, cater to each of these small but demanding customers. For example, each insisted on a modern data network, but Lucent, because of its AT&T ancestry, was weak on data. To fill the holes, Endlich says, Lucent executed a rash of mergers and acquisitions (its second error), including paying $4.5 billion for one company, Chromatis, that had yet to make a sale. Despite the public homage it paid to Bell Labs, Lucent was too impatient to wait for its researchers to develop new products. Rather, it made 38 acquisitions at a frenetic pace, while never integrating them into a seamless whole.

Lucent's third mistake was ignoring the pleas of its homegrown technologists by delaying the development of a higher-bandwidth optical system, the OC-192. As a result, Nortel, once an afterthought in optical equipment, commandeered a 90 percent share of the OC-192 market.

This leads to the fourth and most harmful act of foolishness: Lucent's efforts to satisfy Wall Street by misrepresenting its sales. Carly Fiorina, Endlich says, "set the tone" among Lucent's aggressive salespeople, but she left the company (to run Hewlett-Packard) in 1999, before Lucent's sales practices got

out of hand. The fault lies with the company's CEO: Endlich ably demonstrates how Rich McGinn became wedded to the notion of 20 percent annual revenue growth, a goal he laid out to security analysts in 1998. This was an extraordinary rate for a company with nearly $30 billion in sales. When the results inevitably failed to measure up, Lucent resorted to accounting games. Revenue mysteriously appeared in quarters where it did not belong. Customers were persuaded "to take delivery of items they had not ordered." And so forth.

The real risk in forecasting results isn't that companies may disappoint Wall Street; when expectations are unrealistic, they *should* disappoint. The danger is that managers put their organizations under mortal strain to meet unrealistic goals.

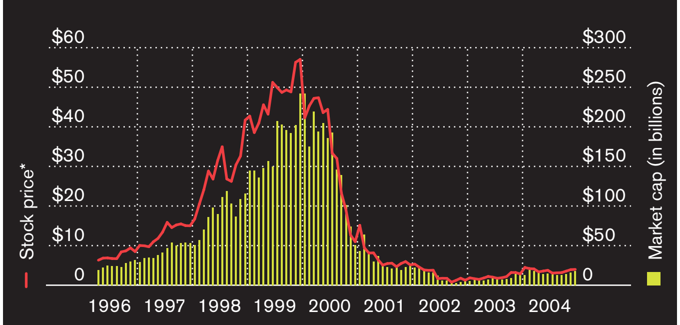
Ultimately, the fixation with stock price corrupted not only Lucent's reporting but also its behavior. "You manage what you measure" is an old manager's maxim. McGinn measured revenue. His sales tactics moved from the aggressive to the self-destructive as Lucent marked down its products by absurd amounts. Customers who got hip to Lucent's weird desperation would delay placing new orders until the end of a quarter, when the pressure on Lucent was greatest. Contracts were reviewed up until 11:59 P.M. on New Year's Eve. One sales executive required her troops to publicly pledge to specific volume goals, as though selling switches was some sort of charity drive.

To further inflate sales, Lucent committed a grotesque $8 billion to customer financing. At some point, Lucent wasn't selling equipment any more; it was giving stuff away and labeling it a sale. When McGinn's controller told him that "One way or another, we will make it" to the next quarter's sales targets, the "other way" included accounting contrivances of which investors like my cousin did not have the faintest notion.

Endlich reports all of this, but she cannot quite bring herself to censure Lucent's executives. After documenting numerous instances of deception, she concludes, "The sum total of these accounting manipulations was not fraud but a less-than-entirely-clear picture of how and where Lucent was making its money." This sentence is unfortunate: evasive and legalistic.

Going for Broke

After peaking at a market cap of more than $250 billion in December 1999, Lucent Technologies is now worth only about $17 billion, a drop of more than 90 percent.



*PRICE ADJUSTED FOR DIVIDENDS AND SPLITS. DATA AS OF DECEMBER 1, 2004. SOURCE: REVERE DATA

She stresses that Lucent's executives weren't criminally charged with "wrongdoing," but deceiving the largest shareholder base in America seems wrong enough. Worse, she pads her account with the retrospective opinions of the major players, which further shades the story in a forgiving tone. In her summing-up, Endlich concludes, "To this day McGinn does not believe that he was overreaching Lucent's abilities in the goals he set in 2000." By this point in the book, our interest in McGinn's opinion should be rather small. Moreover, the remark misses the point. Lucent's problem wasn't that its targets "overreached" but that McGinn employed them to drive operations. In the end, Lucent (and Bell Labs along with it) shrank beyond recognition, and its sales plummeted to levels last seen in the 1980s. Lucent's story is really the story of American business in the late 1990s, when executives betrayed their supposed devotion to "shareholder value" in order to pump up their stocks in the short term—to their shareholders' later misery.

Seeing the Emperor without a Switch

So was all of this unforeseeable? As a matter of fact, it was *foreseen.* Carley Cunniff, an officer of Sequoia (since retired), answered my cousin on the morning of April 14, 2000. "I'm not a technology analyst," Cunniff volunteered, "but I did go through Lucent's annual report....As a financial analyst, I can tell you that you need to be Sherlock Holmes in order to figure out what the heck Lucent's earning." Those earnings were not, she said, what a casual reader of Lucent's press releases would have guessed. "For example," she continued, "Lucent is considered a great growth stock. Let me ask you in this room, what rate would you guess Lucent's domestic revenues are growing at—[bearing in mind that] this is one of the great technology boom periods of all time?"

The number Cunniff proposed wasn't McGinn's magical 20 percent; it was half that rate. She went on to detail how Lucent was financing its customers, many of them overseas (where some of its dubious sales were occurring). "[Lucent's] balance sheet is starting to explode," she said. "Its receivables are going way up....So they're not getting that cash back." Needless to say, Lucent's $41 stock price, considered depressed at the time, didn't strike her as undervalued. Two and a half years later, Lucent's share price was worth less than a dollar.

Even after the Sequoia meeting, McGinn kept promising 20 percent annual growth. Remarkably, after McGinn was fired, Henry Schact, who succeeded him, continued to "call out quarters," Endlich observes. "Each time he set a target date, a specific quarter, and each time he missed the mark."

The lessons of Lucent haven't been learned. Public companies continue to give Wall Street guidance in advance of each quarter, then labor furiously to match expectations. The ritual is so ingrained that we have forgotten that it serves no useful purpose. Endlich notes that predictability is valued by investors, and that "one can only speculate" what might befall a company that refuses to play the game. But Berkshire Hathaway doesn't play it, nor does Google—both tolerably successful companies. ■

Roger Lowenstein is the author of Origins of the Crash: The Great Bubble and Its Undoing *and* When Genius Failed: The Rise and Fall of Long-Term Capital Management.

The End of Oil?

There are good signs that worldwide oil production is declining. Best hold on tight.

BY MARK WILLIAMS

TIM JOHNSON/AP PHOTO

Texas Tea Leaves

Beyond Oil: The View from Hubbert's Peak
By Kenneth S. Deffeyes
Hill and Wang, 2005, $24.00

If the actions—rather than the words—of the oil business's major players provide the best gauge of how they see the future, then ponder the following. Crude oil prices have doubled since 2001, but oil companies have increased their budgets for exploring new oil fields by only a small fraction. Likewise, U.S. refineries are working close to capacity, yet no new refinery has been constructed since 1976. And oil tankers are fully booked, but outdated ships are being decommissioned faster than new ones are being built.

If those clues weren't enough, here's a news item that came out of Saudi Arabia on March 6, 2003. Though it went largely unremarked, the kingdom's announcement that it could not produce more oil in response to the Iraq War was of historic importance. As Kenneth Deffeyes notes in *Beyond Oil: The View from Hubbert's Peak*, it meant that as of 2003, there was no major underutilized oil source left on the planet. Even as established oil fields have reached their maximum production capacity, there has been disappointing production from new fields. Globally, according to some geologists' estimates, we have discovered 94 percent of all available oil.

The Saudis' announcement arrived right on schedule—at least, once the three-year delay imposed by OPEC's anti-U.S. embargo and production cutbacks of the 1970s was factored in. In 1969, the prominent geologist M. King Hubbert predicted that a graph of world oil production over time would look like a bell curve, with a peak around the year 2000. Thereafter, he argued, production would drop—slowly at first, then ever faster.

Hubbert had a track record as a prophet: his 1956 forecast that U.S. domestic oil production would peak in the early 1970s proved correct. Kenneth Deffeyes, who started out in 1958 as a young petroleum geologist at Shell's Houston labs working alongside Hubbert, became so convinced by the man's theories that by 1963 he had left the oil business, except for occasional consulting work; he is now a professor emeritus of geosciences at Princeton University. In *Beyond Oil*, Deffeyes takes readers through Hubbert's analysis in a highly readable style, even boiling down the complex mathematics into a few pages of graphs.

The prognosis? Deffeyes has no doubt that by 2019, the year in which Hubbert's theories indicate global oil production will drop to 90 percent of current rates, human ingenuity will have found replacement energy sources *(see "What Energy Crisis?," p. 19)*. But Deffeyes is optimistic about the long term only because he believes that by 2010, pressures will grow so intense that they'll create the resolve necessary to develop a new energy economy. In the short term, he foresees continually rising oil prices that force industry after industry closer to the wall. He fears not just escalating resource wars around the world but also mass starvation in some countries, since the 6.4 billion people living on the earth today are fed thanks largely to the successes of the 20th century's "green revolution," which, among other innovations, brought petrochemical-based fertilizers into wide use.

Because 15 years ago we failed to begin developing the new energy sources and technologies we need now, Deffeyes argues, in the immediate future we'll have to rely on what we've got. In *Beyond Oil*, he examines how we might optimize the use of our geologically derived energy sources.

Deffeyes suggests that coal will make a comeback and that Fischer-Tropsch conversion—the process by which the Nazi regime turned coal into gasoline to keep its Panzers running during WWII—might become commonplace. He grants that there'll be an outcry over the ecological costs of burning coal; similarly, there'll be much agonizing as nuclear power plants are again rolled out. But Deffeyes believes that M. King Hubbert, whose 1956 paper predicting the U.S. oil production peak is titled "Nuclear Energy and the Fossil Fuels," was right: nuclear power will be part of our response to decreasing reserves of oil and natural gas, as necessity overrides any political opposition.

Ultimately, says Deffeyes, we may just have to resign ourselves to relying more on coal, wind, and nuclear fission for electricity and switching to high-efficiency diesel and hybrid automobiles in order to ration our remaining oil reserves for as long as possible. Abundant energy from fossil fuels was a one-time gift, Deffeyes concludes, that lifted humanity up from subsistence agriculture and has led to a future based on renewable resources. ■

Mark Williams is a writer who lives in Oakland, CA.

Synopses

EDITED BY MONYA BAKER

Each month brings new investigative tools, new ideas for revolutionary technology, and revolutionary applications of existing technology. No one can know today which will matter most tomorrow. But these represent *Technology Review*'s best prediction.

INFORMATION TECHNOLOGY

Photoshop Sleuths

An algorithm sniffs out digital alterations

CONTEXT: Photographs used to be a reliable source of evidence, but the advent of digital cameras and photo-editing software has made every picture a potential scam. The skillful user of Adobe Photoshop and other tools can produce realistic images of imaginary scenes. As Dartmouth University computer scientists Alin Popescu and Hany Farid note, the Los Angeles *Times* unwittingly ran an altered photograph from the war in Iraq on its front page. To help defend against these types of forgeries, Popescu and Farid have published a new image-processing algorithm that detects photographic fakery.

METHODS AND RESULTS: When forgers modify an image, they often insert elements taken from other photographs or from other sections of the same photograph; these insertions need to be distorted, resized, or rotated to fit in with the rest of the image. Even when no new elements are added, digital manipulations may leave telltale signs of "re-sampling." For example, to double an image's size, software inserts a new pixel between every pair of neighboring pixels in the original image. The new pixels are a combination of the pixels surrounding them in the original image—the result of interpolation. Such regularity rarely occurs in natural images and often produces patterns that Popescu and Farid's software can detect, even when they're unapparent to the naked eye. In trials employing 50 images selected at random from a database of 200, Popescu and Farid's method found nearly all cases of enlargement greater than 1 percent and most cases of rotation that required interpolation. Some cases of shrinking could also be detected.

WHY IT MATTERS: Current forgery detection techniques, which are vital for screening news items and intelligence, leave much to be desired. Digital watermarking works only when someone has had the foresight to insert hidden information into an image file to prevent tampering. In contrast, Popescu and Farid's method can be applied automatically to any image file. However, the method is not foolproof: for example, it cannot detect cases of shrinking without interpolation. Also, data compression, used in JPEG files, and noise interfere with the algorithm. Nonetheless, the new software makes it harder for a digital photograph to lie.

Source: Popescu, A. C. and H. Farid. 2005. Exposing digital forgeries by detecting traces of re-sampling. *IEEE Transactions on Signal Processing* (in press).

Once More, With Volume

Hand gestures control computer graphics

CONTEXT: Video games, design software, and scientific visualization technologies routinely use 3-D graphics. Typically, users interact with 3-D graphics on flat computer screens and cannot grab, move, or rotate graphical representations as they can real physical objects. Even the most advanced stereoscopic displays, like those used in virtual-reality systems, require head-mounted displays, which restrict viewers' range of motion, obstruct peripheral vision, and cause discomfort. Now, researchers at the University of Toronto have created a system that frees 3-D graphics from such constraints.

METHODS AND RESULTS: Key to the system is a "volumetric" display, one that lets multiple users view graphics from any angle without wearing headgear. Tovi Grossman and his colleagues used a swept-volume display, which spins a series of 2-D images around an axis fast enough that humans perceive them as a 3-D image. The researchers created a way for users to manually interact with their display, which is housed in a clear plastic dome. Cameras track special rings worn by the users, who can select 3-D objects by pointing at them and drag them by moving their fingers across the display sphere. Using both hands, users can stretch or shrink objects, or specify the axis about which an object should rotate.

WHY IT MATTERS: While the new display does not provide sensory feedback, it permits the control of 3-D graphics through hand gestures similar to those whereby people manipulate real objects. The technology eliminates the need for joysticks or virtual representations of users and paves the way for 3-D graphics applications that anyone can use with minimal training. Volumetric displays, once found only in expensive research prototypes, have become commercially available. The To-

ronto researchers' interface could hasten the day that they are routinely used by scientists designing drug molecules, doctors planning surgeries, architects, engineers, and, of course, gamers.

Source: Grossman, T., D. Wigdor, and R. Balakrishnan. 2004. Multi-finger gestural interaction with 3D volumetric displays. *Proceedings of the ACM Symposium on User Interface Software and Technology*, pp. 61-70.

Model Sensors

Statistics yields better data with less battery power

CONTEXT: Sensor networks are collections of small devices that measure local conditions like temperature or light intensity. The devices, sometimes called sensor "motes," transmit data wirelessly to monitoring stations. Sensor networks could let soldiers track enemy tanks remotely, engineers gauge the structural integrity of buildings, or scientists monitor animals in their natural habitats. But one barrier to their widespread use is the difficulty of coaxing reliable information from motes whose batteries are low or whose connectivity is intermittent. Motes tend to be widely scattered and often malfunction; but a sensor network that represents the world inaccurately or incompletely is of limited use. Now researchers at Intel Research Berkeley and their collaborators have shown that new statistical techniques can compensate for some of these flaws.

METHODS AND RESULTS: A statistical model based on previous data from a sensor network can correct for biases caused by malfunctioning or poorly placed sensors. It can also tailor the network's performance to specific tasks: someone querying the network can specify the accuracy of the response, and the model will automatically determine which data are needed. Pulling in just the required data means that precious battery power is not wasted on extra measurements and transmissions. Amol Deshpande and his colleagues developed a query system enhanced with statistical techniques and tested it in sensor motes deployed over a redwood tree in Berkeley, CA. The system answered queries—such as what the temperature at a certain spot was—highly accurately (95 percent confidence), often performing only one-fortieth the number of observations previously required.

WHY IT MATTERS: Sensor networks promise to transform environmental monitoring, military surveillance, and inventory management. Now, the data that a sensor network gathers can be interpreted and used with more confidence. When high accuracy is necessary, a network using a statistical model like Intel's will collect more data. When rougher estimates are acceptable, using statistical models reduces the battery power consumed by sensor motes. A longer battery life for sensor motes is a great boon, especially for motes distributed in hostile or inaccessible terrains. Although Intel's models and methods can still be improved, its technique greatly expands sensor networks' utility in the real world.

Source: Deshpande, A. et al. 2004. Model-driven data acquisition in sensor networks. *Proceedings of the 30th International Conference on Very Large Data Bases*, pp. 588-599.

BIOTECHNOLOGY

Bacteria Defeat Tumors

Infections train the immune system to destroy cancerous cells

CONTEXT: Many clinicians and researchers attempt to treat cancer without resorting to debilitating chemo- and radiotherapy. But even "magic bullet" drugs, which hone in specifically on cancer cells, have serious side effects. A better option may be to train a patient's own immune system to attack tumors. Now researchers at Johns Hopkins University, led by Bert Vogelstein, have found that bacteria show promise as a means of priming the immune system, and might be used to treat cancer of the liver, lungs, and pancreas.

METHODS AND RESULTS: Animals with cancerous tumors were injected with bacteria that thrive in the oxygen-deprived centers of solid tumors and die off in healthy, oxygenated tissues. The researchers hoped that the bacteria would destroy the tumors from the inside out, leaving an outer rim of cancer cells that could be more easily treated with standard therapies. The bacteria did just that. However, the researchers also found that the infection frequently prompted the subject's immune system to recognize the cancer and attack it. In 23 of 70 test animals, this immune response destroyed the remains of the tumor without additional therapy. Even after the bacterial infections cleared, the animals' immune systems attacked newly injected cancerous cells of the type successfully treated. The treatment had similar effects in both mice and rabbits, making it plausible that it could also work in other species, including humans.

WHY IT MATTERS: The ideal cancer treatment, as currently imagined, would kill cancer cells without damaging healthy ones. The Hopkins researchers' method goes even further, preparing the immune system to defeat cancer cells left behind after a tumor is destroyed. So far, bacterial therapy does not appear to have the side effects associated with current cancer treatments. Of course, many promising treatments in animals have disappointed in human tests. But if the therapy does prove safe and effective for humans, cancer patients could be looking at much more successful and comfortable treatments in the future.

Source: Agrawal, N. et al. 2004. Bacteriolytic therapy can generate a potent immune response against experimental tumors. *Proceedings of the National Academy of Sciences* 101: 15172-15177.

Trouble in the Cell's Power Plant

Aging diseases link to a mitochondria gene

CONTEXT: If you have high blood pressure, you're more likely to be obese and to have high cholesterol and a host of other unhealthy conditions. Recent evidence suggests that obesity keeps the body's cells from responding properly to

blood sugar, leading to diabetes. However, why these conditions are associated with high blood pressure is still poorly understood. A team of researchers from Yale University and the State University of New York Upstate Medical University sought an answer in genetics and found one in mitochondria. Most cells contain hundreds of mitochondria, rod-shaped structures that originated billions of years ago when a cell engulfed a bacterium but did not destroy it. Now, the bacterium's descendants help the body's cells convert food into energy.

METHODS AND RESULTS: Frederick Wilson of Yale and his colleagues studied a family with a high incidence of conditions associated with hypertension and tracked inheritance in 142 blood relatives over four generations. After adjusting for differences in age, weight, and medication use, the researchers found a clear pattern of inheritance. All the conditions descended through the maternal line, indicating that the culprit gene was mitochondrial. (A person's mitochondria derive from those originally present in the ovum and have their own, bacteria-like DNA.) A full sequence of affected family members' mitochondrial genome revealed 14 differences from standard sequences. Thirteen had been previously reported to have no impact. The 14th was new and was mapped to a gene for a transfer RNA, a molecule essential to building proteins. In fact, the gene is constant across animals, fungi, plants, and even bacteria.

WHY IT MATTERS: Against a noisy backdrop of studies showing how heart disease, depression, and other complex diseases can be attributed to small effects from many genes, Wilson and his colleagues' research shows that a single gene can be tied to many disease-associated conditions. More importantly, the research pins responsibility for several diseases on mitochondria, whose function declines with age. Those seeking the fountain of youth, or just hoping to stave off the ravages of old age, may benefit from further studies of these vestiges of ancient bacteria.

Source: Wilson, F. H. et al. 2004. A cluster of metabolic defects caused by mutation in a mitochondrial tRNA. *Science* 306: 1190-1194.

Embryonic Stem Cells Made Easy?

A technique for creating stem cells may be less labor intensive—and less controversial

CONTEXT: The potential therapeutic value of embryonic stem cells is so great that hundreds if not thousands of scientists are pursuing them, and Californians recently voted to back stem cell research with billions of state dollars. Currently, creating embryonic-stem-cell lines requires destroying a five- to seven-day-old human embryo, or blastocyst, which resembles a hollow ball. Difficult microsurgery and precise timing requirements mean that fewer than one in five attempts results in a viable line.

Earlier-stage embryos—four-day-old solid balls of cells called morulas—are easier to grow and manipulate. Nick Strelchenko's research team at the Reproductive Genetics Institute in Chicago has for the first time created stem cell lines from human embryos in this stage of development.

METHODS AND RESULTS: Using embryos from an in vitro fertilization clinic, the researchers attempted to make stem cell lines from a few dozen morulas and blastocysts. For each embryo, the likelihood of establishing a cell line was just under 20 percent. Cells derived from both kinds of embryo produced several molecules that are characteristic of human embryonic stem cells. They were also able to spontaneously develop into several more-specialized cell types, a defining trait of embryonic stem cells.

WHY IT MATTERS: About half of all embryos die before reaching the blastocyst stage, and the techniques for deriving cell lines from blastocysts are time consuming. If additional studies show that morula-derived embryonic stem cells are as promising as their blastocyst-derived counterparts, scientists will have a new, more convenient source for stem cell lines. Also, although Strelchenko and his colleagues used entire morulas to generate stem cells, it may be possible to separate individual cells from a morula and retain a viable embryo. If these extracted cells prove able to generate stem cells, then the creation of embryonic stem cells would no longer require the destruction of an embryo.

In any case, Strelchenko and his colleagues' results should inform and encourage the multitude of scientists and clinicians currently searching for ways to sidestep this ethical controversy.

Source: Strelchenko, N. et al. 2004. Morula-derived human embryonic stem cells. *Reproductive BioMedicine Online* 9:623-629.

NANOTECHNOLOGY

Low-Power Organics

Better insulation helps plastic circuits flex toward the market

CONTEXT: Computer chips contain millions of transistors made of silicon. But silicon is too brittle to be used in applications such as flexible displays and smart fabrics that monitor vital signs. Such products will require new materials, ideally plastics. But all "organic transistors" so far have required voltages too high and consumed power too quickly to be viable. Researchers from Siemens spin-off Infineon, the University of Stuttgart, and MIT have created organic transistors that seem to surmount these barriers.

METHODS AND RESULTS: A transistor is an electronic switch that flips when voltage is applied to a wire on top of a semiconductor. However, if the wire comes in contact with the semiconductor, the circuit will leak, or waste, electrical current. So transistors are insulated from the wires that flip them by a layer of material called a "gate dielectric." Fabricating these layers is perhaps the most challenging aspect of building transistors: thinner layers allow operation at lower voltages but are prone to pinhole-like defects through which current can leak. Up to now, organic transistors used dielectrics more than 100 nanometers thick and required more than 20 volts to operate. Infineon's Marcus Halik and his team grew a pinhole-free film

only 2.5 nanometers thick from molecules that "self-assemble." Transistors placed atop this film switched using less than two volts and drew even less current than transistors in conventional silicon chips.

WHY IT MATTERS: Organic transistors could be used to build displays that bend like paper, cloth that computes, and cheap electronic bar codes. By demonstrating low-voltage organic transistors, researchers may have eliminated a barrier to the commercialization of such devices.

Source: Halik, M. et al. 2004. Low-voltage organic transistors with an amorphous molecular gate dielectric. *Nature* 431:963-966.

Super-sensitive Screen

Better virus detection through nanowires

CONTEXT: Health-care providers would benefit greatly from a simple, inexpensive method for determining whether a patient's runny nose or upset stomach signifies a virus—or something else. A medical lab can identify an infection from a tissue swab, but only after the time-consuming and expensive process of sample preparation and analysis.

Far better would be a device that could interact with a virus at the cellular level, producing an electrical signal that could be interpreted by computer chips and other electronics. Such a system would, in theory at least, be cheaper than existing diagnostic technologies; it could also potentially screen numerous viruses at once and determine the presence or absence of any of them almost instantly. Silicon nanowires are one promising candidate as the detection technology, because they are about the same size as biological particles and could respond to their presence with great sensitivity.

Now, seminal work in the laboratories of Charles Lieber, a chemist and pioneer in the field of nanotechnology, and Xiaowei Zhuang at Harvard University has demonstrated that such a nanowire system can be built and can detect single virus particles—a milestone in the development of a new generation of ultrasensitive nanosensors.

METHODS AND RESULTS: Silicon nanowires were "decorated" with virus-specific antibodies. When a virus bonded with one of the antibodies, the charged proteins on the virus's surface changed the nanowire's conductivity, in much the way that an electrical charge can turn a transistor on or off. Viruses could be detected in seconds or minutes, and one type of virus would show up clearly even in the presence of another. The process worked even with samples that had not been extensively purified, though the researchers did not attempt to directly test samples of fluids such as plasma.

WHY IT MATTERS: The Harvard researchers' work is a breakthrough in the application of nanotechnology to the improvement of biosensors. The first use of such a virus detection system would likely come in a pharmaceutical laboratory: replacing the antibodies with potential drug molecules could help identify antiviral drugs. Such a system could make drug discovery faster and more efficient.

Outside of the lab, the technique could yield a simple biochip test that might be performed in any doctor's office, day care center, or private home. Of course, nanowires are not necessarily the only means of building such a chip, and other technologies may yet prove to be more robust or less expensive. But the idea of selling a biochip every time a toddler sneezes is enough to ensure that, somewhere, a venture capitalist is smiling.

Source: Patolsky, F. et al. 2004. Electrical detection of single viruses. *Proceedings of the National Academy of Sciences* 101:14017-14022.

Trip the Light Fantastic

Teaching old optics new tricks could lead to novel sensors and interfaces

CONTEXT: Thousands of kilometers of optical fibers have been laid under roads and even oceans, where they quietly and competently transmit telephone calls, Internet downloads, and television shows in the form of light pulses. Traditionally, these glass fibers have been simple conduits; the less they interact with the rest of the world, the better they perform. Now researchers in the laboratory of Yoel Fink at MIT have turned that notion on its head, creating a fiber that detects as well as transmits light and demonstrating a much more economical way to make large-scale light sensors.

METHODS AND RESULTS: In the conventional fiber-drawing process, a relatively thick slug, or preform, of glass is heated in a furnace and carefully stretched. To create their light-sensing fiber, Fink and Mehmet Bayindir's team used a complicated preform with three main active ingredients, including a semiconductor whose conductivity improves dramatically when it is illuminated; tin wires, which help conduct electricity; and a nanostructured mirror, which selectively confines light of a specific wavelength to the fiber's core. The original preforms were approximately 30 millimeters across, and they were drawn out to form fibers a millimeter or less in diameter.

A light shone on the resulting fiber at any point along its length can be detected as a change in electrical conductivity more than ten meters away. The researchers wove a collection of these fibers together to create a two-dimensional grid, 30 by 30 centimeters square, which tracked the position of a light beam shone onto its surface.

WHY IT MATTERS: A typical light sensor is an array of many individual detectors. As a consequence, it's limited in size: combining thousands or millions of detectors can be prohibitively expensive. By weaving together lines of fibers instead of assembling individual dots, the MIT researchers have found a way to drastically reduce the cost of spanning large areas with light detectors.

That could lead to the development of completely new kinds of optical devices and interfaces, such as a projection screen that can respond to a user's laser pointer rather than requiring a conventional computer mouse.

Source: Bayindir, M. et al. 2004. Metal-insulator-semiconductor optoelectronic fibres. *Nature* 431:826-829.

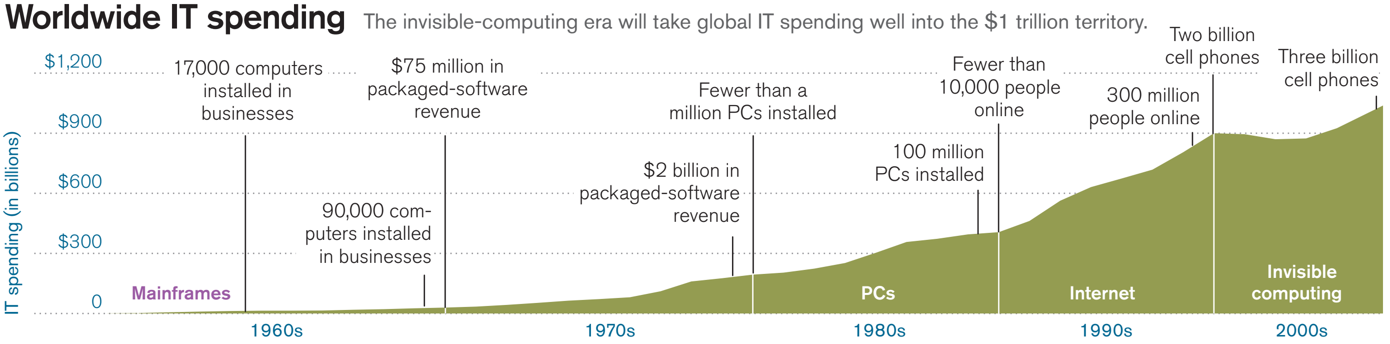
Invisible Computing Is Hard to Miss

WHETHER IT'S CALLED "invisible computing" or "pervasive" or "ubiquitous" computing, the integration of technology into our business and personal lives is well upon us. Invisible computing promises a world filled with networked devices—not just desktop or laptop computers but cars, toys, cell phones, RFID tags, and even kitchen utensils—that communicate with each other. And part of its invisibility is that it should impose no major learning curve on consumers. Driven by advances in wireless and Web-services technologies, customer relationship management, asset management, and instant messaging, invisible computing will deliver the productivity benefits long promised by computing's pioneers.

Over the next decade, traffic from the edges of the network to its center will become almost as heavy as the traffic flowing from servers to clients. The effect on product architecture will be significant: for example, servers will need to be able to handle a 12-fold increase in client payload by 2012. IDC pegs the invisible-computing market at $675 billion by 2008 and says the vast majority of revenue will flow to established technology and service providers. **MARYANN JONES THOMPSON**

Worldwide IT spending

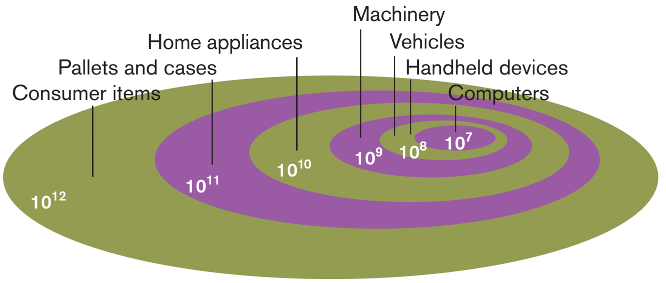
The invisible-computing era will take global IT spending well into the $1 trillion territory.



SOURCES: IDC, TECHNOLOGY REVIEW

Devices that can be networked

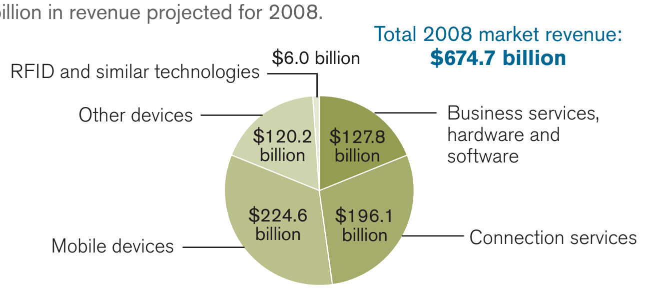
Noncomputer objects will soon account for the vast majority of networked devices. The market for such things is enormous.



SOURCE: FORRESTER RESEARCH

Invisible-computing forecast

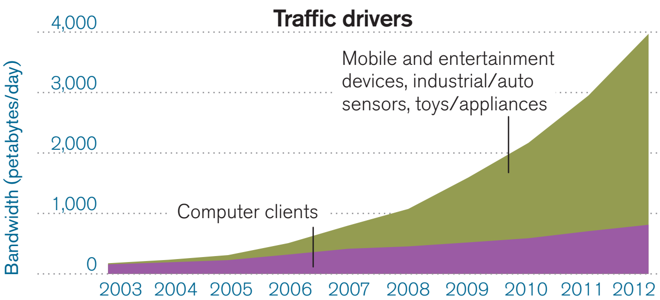
While new technologies will likely spawn new companies, existing IT vendors and service providers will reap the vast majority of the $675 billion in revenue projected for 2008.

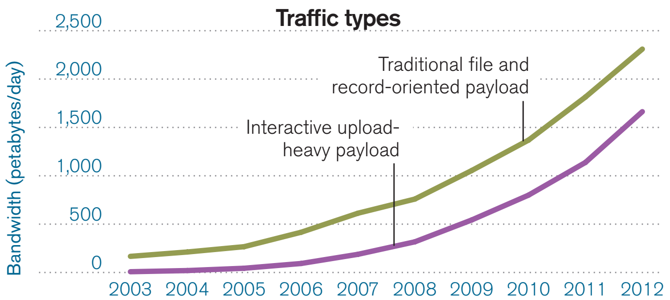


SOURCE: IDC

Network payload forecast

Invisible computing will turn the network inside out: noncomputer clients at the edge of the network will handle an increasing share of data transmission.





SOURCE: IDC

Life Vest

Lester Shubin and Nicholas Montanarelli turned Kevlar into lifesaving armor

On the website of the Kevlar survivors' club are stories from many of its 2,800 members, mainly police officers describing how they owe their lives to the bullet-resistant vest. They should also be thanking Lester Shubin and Nicholas Montanarelli, who in the 1970s, while working for the U.S. government, led the development of the vest. And while they're at it, they might also salute a small herd of goats that gave their lives in testing the new body armor.

Before the 1970s, soldiers had to make do with heavy, bulky nylon flak jackets that could resist shrapnel but were ineffective against bullets. Police officers found the jackets of little use, and they desperately needed something better.

It was at around this time that Kevlar appeared on the scene. DuPont chemists invented this synthetic fiber in 1965 as a material to replace the steel belts in tires. By the late 1960s, the U.S. Army was evaluating it as a possible replacement for nylon in its flak jackets.

Shubin, who was a technology assessment program manager with the National Institute of Justice (NIJ) in Washington, DC, found out about Kevlar from Montanarelli, an army technology specialist. By the early 1970s, the two had begun testing the material at an army firing range in Maryland. They folded a piece of Kevlar a few times, stuck it to a phone book, and shot at it with a .38-caliber gun. "The bullets bounced back," remembers Shubin, 79, now living in Fairfax, VA.

At around the time of these tests, Shubin saw a photograph of a man suspended from a beam by a thin Kevlar fiber. Five times stronger than steel, Kevlar was also lightweight and flexible. "It seemed to me that you could get good body armor out of it," says Shubin. "We were getting police shot every day. I thought, this could be the way to protect them."

In 1972, the NIJ–an agency within the U.S. Department of Justice–launched a research program to develop lightweight body armor. Kevlar soon emerged as the most promising material.

Over the next five years, the National Institute of Justice would invest $3 million in the body armor project led by Shubin and Montanarelli and carried out by the U.S. Army. In a series of early tests, the two men drafted 100 goats to help. The 40- to 50-kilogram animals, it was thought, would be a good model for humans and had been used before to study the effects of trauma. The army researchers strapped seven-ply, 14-inch squares of Kevlar onto the anesthetized goats, propped them up, and shot at their hearts, spinal cords, livers, and lungs. They then monitored the goats' heart rates and blood gas levels to check for lung injury. After 24 hours, one goat died. Autopsies on the other goats revealed wounds that were not life threatening.

The body armor project entered its final phase in 1975 with the field-testing of 5,000 vests by police officers in 15 cities with higher-than-average officer assault rates. While some officers complained that the vests were hot, they soon found that they could wear the body armor and still do their jobs. Just before Christmas of that year, a Seattle policeman was shot in the chest in the line of duty. He survived thanks to the bullet-resistant vest he was wearing as part of the field test. It was the first real proof of the vest's protective power. "I was elated," says Shubin, "especially after talking to his wife. She was almost hysterical."

Shubin and Montanarelli issued a report in 1976 concluding that their vest worked. "The police really took to it," recalls Shubin. Moreover, this project sped up the army's parallel efforts in developing Kevlar body armor for soldiers, says Montanarelli. The army began using Kevlar vests by the early 1980s. What started off as tire material became a lifesaving piece of equipment widely used by law enforcement and soldiers. CORIE LOK

Marines engaged in Lebanon in 1983, around the time the U.S. began using Kevlar vests.

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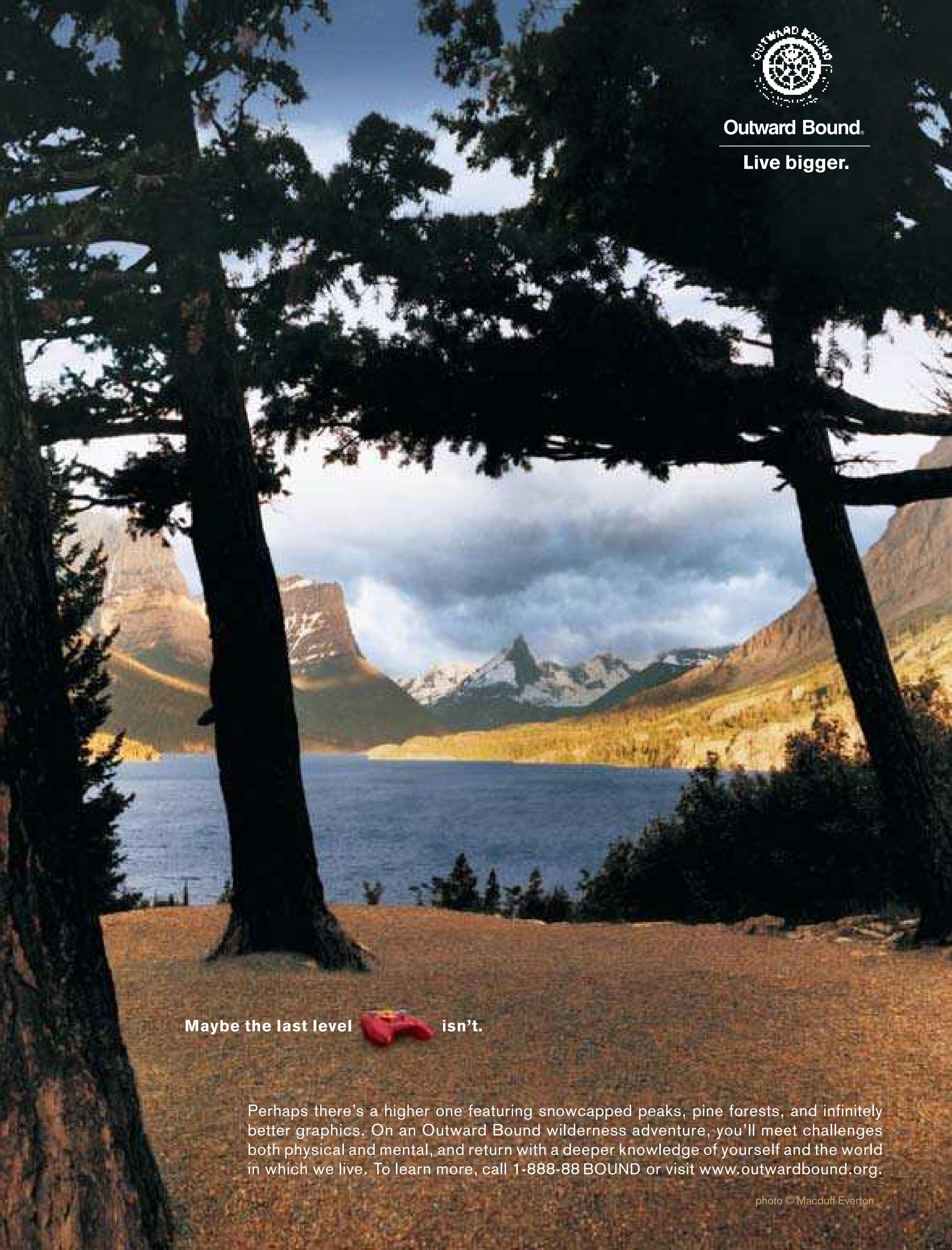
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